THE VEGETATION AND SOILS OF AFRICA

H. L. SHANTZ
C. F. MARBUT

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THE VEGETATION AND SOILS OF AFRICA

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WITH A SECTION ON THE LAND CLASSIFICATION OF AFRICA BY THE JOINT AUTHORS

AND A NOTE ON A RAINFALL MAP OF AFRICA
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CONTENTS

CHAPTER PAGE

PREFACE vii

PART I

The Vegetation of Africa

By H. L. SHANTZ

I THE TYPES OF AFRICAN VEGETATION 3

II THE FORESTS 23

III THE GRASSLANDS 50

IV THE DESERTS 76

LIST OF REFERENCES 85

PART II

The Soils of Africa

By C. F. MARBUT

V THE PRINCIPLES OF SOIL SCIENCE 115

VI THE STUDY OF AFRICAN SOILS: PAST CONTRIBUTIONS AND THE PRESENT ATTEMPT 131

VII THE SOILS OF TEMPERATE AND SUBTROPICAL AFRICA (SOUTH AFRICA, SUDAN, ATLAS REGION) 142

VIII THE SOILS OF ARID AFRICA (SAHARA AND DESERTS OF SOUTHWEST AND NORTHEAST AFRICA) . . . 179

IX THE SOILS OF TROPICAL AFRICA (CENTRAL AFRICA AND GUINEA) 181

TABLE OF CHEMICAL ANALYSES OF AFRICAN SOILS . 218

PART III

Land Classification of Africa

By H. L. SHANTZ and C. F. MARBUT

CHAPTER PAGE

X THE LANDS OF AFRICA ACCORDING TO THEIR POTENTIAL PRODUCTIVITY 225

NOTE ON THE RAINFALL MAP OF AFRICA, by J. B. KINCER 245

INDEX 249

LIST OF ILLUSTRATIONS

FIG.		PAGE
1	Map of Africa showing the route of H. L. Shantz, the localities at which soil samples were collected, and the present territorial divisions of the continent. Scale 1:55,000,000	viii-ix

Vegetation

2	Mangrove forest	Facing 24
3	Tropical rain forest	25
4	Tropical rain forest: a native plantation	28
5	Tropical rain forest: a coffee plantation	29
6	Temperate rain forest	32
7	Temperate rain forest	33
8	Temperate rain forest: native fields	34
9	Temperate rain forest: mixed culture	35
10	Oak-conifer forest	36
11	Dry forest	37
12	Thorn forest	44
13	Temperate brush	45
14	Temperate brush: a vineyard	46
15	An oasis	48
16	High grass-low tree savana	50
17	High grass-low tree savana: native agriculture	51
18	High grass-low tree savana: a coffee plantation	52
19	High grass-low tree savana: a plantation of manioc	53
20	Acacia-tall grass savana	56
21	Acacia-tall grass savana	57
22	Acacia-tall grass savana: a native field of sorghum	57
23	Acacia-tall grass savana: a native planting of sweet potato	58
24	Acacia-tall grass savana: an orange orchard	59
25	Tall grass	60
26	Tall grass	61
27	Acacia-desert grass savana	64
28	Acacia-desert grass savana	65
29	Desert grass	66

FIG. PAGE

30 Mountain grassland 67
31 Mountain grassland 68
32 Mountain grassland: a native field of eleusine 69
33 Dwarf palm-temperate grass 72
34 Marsh grass 73
35 Marsh grass: oil palms 74
36 Desert shrub-desert grass 76
37 Desert shrub 80
38 Salt desert shrub 81
39 Desert 82

Soils

40 Section of chestnut brown soil at Taungs, Cape Province 158
41 Section of chernozem at Bulawayo, Southern Rhodesia Facing 158
42 Section of chernozem, Njoro, Rift Valley, Kenya Colony 158
43 Detail of Fig. 41 159
44 Section of red loam, Moshi, Tanganyika Territory . . . 194
45 Section of red loam, Embu, lower slopes of Mount Kenya, Kenya Colony 194
46 Section of red loam, Kalule Sud, Belgian Congo 194
47 Section of red loam, Lualaba River at Malele, Belgian Congo 194
48 Detail of Fig. 46 195
49 Section of red loam, Port Bell, Uganda 195
50 Building blocks, probably lateritic if not laterite, between Mesindi and Butiaba, Uganda 195

PLATES
(In separate case)

PL.

I Vegetation map of Africa, by H. L. Shantz. 1:10,000,000. With inset: Soil map of Africa, by C. F. Marbut. 1:25,000,000.

II. Land classification map of Africa, by H. L. Shantz and C. F. Marbut. 1:10,000,000. With inset: Rainfall map of Africa, by J. B. Kincer. 1:25,000,000.

All the photographs in this book are by H. L. Shantz, except Figs. 10 and 33, whose sources are acknowledged in the legends.

PREFACE

The work of which this book is the outcome was begun in 1918 at the instigation of the "Inquiry," the organization of technical advisers who prepared data for the American Commission to Negotiate Peace. It was then in charge of N. M. Fenneman. In the Bureau of Plant Industry of the U. S. Department of Agriculture a committee was appointed to produce a vegetation map of Africa. In the Bureau of Soils and in the Weather Bureau of the same department provision was made for the preparation respectively of a soil map and a rainfall map of the continent. The committee entrusted with the preparation of the vegetation map consisted of T. H. Kearney, G. N. Collins, and H. L. Shantz (chairman). T. H. Kearney outlined the vegetation of North Africa, H. L. Shantz of the rest of the continent. The soil map was prepared by C. F. Marbut, the rainfall map by J. B. Kincer. The land classification map was prepared, as explained in Chapter X, by combining the soil map and the vegetation map. In 1919–20 H. L. Shantz traversed the continent from Cape Town to Cairo (for route, see map, Fig. 1). On his return he worked over his original material, revised the vegetation map, and supplied photographs and text. The soil map was likewise revised as a result of some twenty soil samples collected by H. L. Shantz on his trip (for localities, see Fig. 1). The land classification map was correspondingly revised. It is these revised versions of the three maps and related texts, and the original version of the rainfall map, that are presented herewith.

Acknowledgments are due to many for assistance in various ways. As regards the vegetation map and text especial acknowledgment should be made to the following persons: to Dr. T. H. Kearney, who as a member of the Bureau Committee first sketched the vegetation of North Africa and reviewed the literature; to M. P. Tucker, who did the drafting of the original map

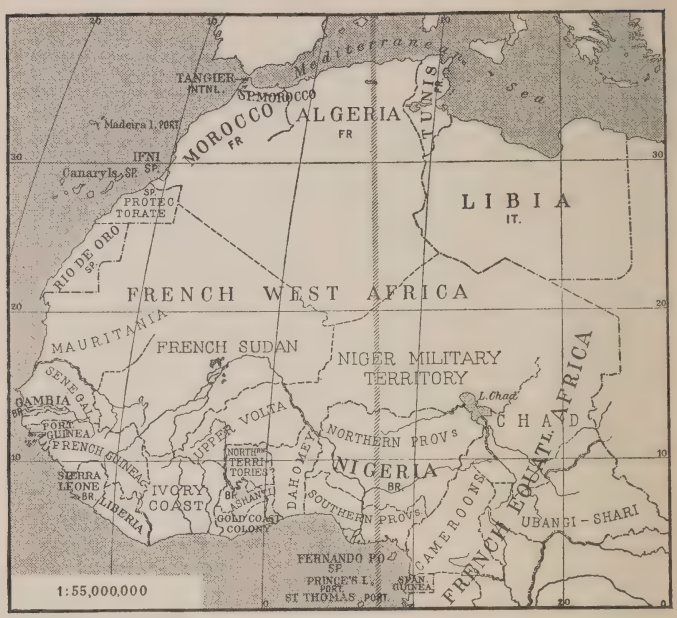

FIG. 1 (consisting of this section and that on the opposite page)—Map of Africa showing the route of H. L. Shantz in 1919–1920, the localities of the soil samples of which chemical analyses are published in this book, and the present territorial divisions of the continent. Scale, 1: 55,000,000. The overlap of both sections is indicated on each section by a shaded line.

and compiled the survey, reconnaissance, and sketch-map data under the direction of H. L. Shantz; to A. C. Atwood for assistance with the list of references; to T. Schaffer, M. Gosline, E. R. Oberly, L. Thurlemann, M. F. Warner, and K. Wead, for abstracting geographical journals, books of travel and exploration, botanical, zoological, anthropological, agricultural, and other scientific literature containing information on the distribution of vegetation; to G. N. Collins for criticism relative to West African vegetation; to Dr. J. Bequaert for criticism relative to Congo vegetation and the forest boundary; to A. Lang and J. P. Chapin for suggestions relative to the northern Congo; to H. C. Raven, who crossed the continent from the Cape to Cairo and furnished notes on the portions of the route not duplicated by

1: 55,000,000
100 0 100 200 300 400 500 MILES
Mediterranean Sea
ALGERIA FR.
TUNIS FR.
LIBIA IT
EGYPT
Port Said
Cairo
ARABIA
Red Sea
Halfa
FRENCH WEST AFRICA
ANGLO-EGYPTIAN SUDAN
Khartum
ERITREA IT
ABYSSINIA
FR. SOMALIL'D.
BRITISH SOMALIL'D.
ITALIAN SOMALIL'D.
NIGER MILITARY TERRITORY
Chad
CHAD
NIGERIA BR
NORTHERN PROV'S
CAMEROONS
FRENCH EQUAT'L AFRICA
UBANGI-SHARI
CONGO
Congo R.
SPAN. GUINEA
GABON
MIDDLE CONGO
BELGIAN
Rejaf
Nimule
UGANDA PROT'E
Entebbe
Lasamis
KENYA COLONY
Kisumu
Meru
L. Victoria
Nairobi
BR
VII
Voi
Kindu
Nyanza
Kongolo
Ngano-Ngano
Kigoma
Moshi
Tanga
Zanzibar
Dar-es-Salaam
CABINDA PORT.
Albertville
TANGANYIKA TERRITORY BR.
PORTUGUESE WEST AFRICA
XVIII
Kafule Sud
Elizabethville
RHODESIA
NASAL'D PROT'S BR.
COMORO IS. FR.
Mozambique Channel
NORTHERN RHODESIA BR
Zambezi R.
Kafue Camp
SOUTH RHODESIA BR.
PORTUGUESE EAST AFRICA
Beira
MADAGASCAR FR
SOUTH WEST AFRICA BR.
BECHUANAL'D PROTECT'E BR
Bulawayo
TRANSVAAL
Pretoria
Mafeking
Vereeniging
Johannesburg
Lourenço Marques
Taungs
Upington
Orange R.
CAPE OF GOOD HOPE
UNION OF SOUTH AFRICA BR
NATAL
Cape Town
Port Elizabeth
by rail by boat by auto on foot Route of H. L. Shantz Aug 1919 – Sept 1920
Localities of soil samples of which chemical analysis is XX is given after Ch X (all, except I, VII, XVIII, XIX, collected by H. L. Shantz)
International boundaries
Internal boundaries
BR, FR, IT, PORT, SP, Abbreviations of national suzerainty

H. L. Shantz; to Agnes Chase for identifications of grasses; and to G. P. Van Eseltine and H. C. Skeels for assistance with the botanical nomenclature.

In the preparation of the section on soils acknowledgments are due to F. A. Barker, R. S. Holmes, G. J. Hough, and W. O. Robinson, all of the Bureau of Soils, for the chemical analyses published at the end of that section.

All the photographs in this work are by H. L. Shantz, with the exception of Figures 10 and 33, whose sources are acknowledged in the legends. The base map on the scale of 1: 5,000,000 on which the various distributions were originally plotted was drawn under the direction of the American Geographical Society for the Inquiry. This base, photographically reduced, has likewise served as base for the present four maps (Pls. I and II, each with inset).

The National Research Council not only approved and encouraged the publication of this volume but generously made an appropriation to cover half the cost of engraving and printing the accompanying maps.

The present work is published with the permission of the Secretary of Agriculture.

PART I

THE VEGETATION OF AFRICA

CHAPTER I

THE TYPES OF AFRICAN VEGETATION

From the standpoint of the distribution of the natural types of vegetation, it is probable that Africa will ultimately be better known than any other continent. Although large parts of the great forests have been destroyed by primitive man and by fire, these may both be regarded as natural causes which have affected the distribution of plants on all continents. Unlike North America and Europe and even portions of Asia, there are on this continent no extensive areas where the original vegetation has been entirely replaced by cultivated crops or man-made forests. It is true that much of Africa has not been explored by the botanist. There still remains a wealth of new species to reward the systematist, and areas untraversed by ecologists or geographers still offer excellent opportunities for investigation. Travelers in this continent have, however, usually regarded note-taking and even map-making as an important part of their journey; and as regards vegetation there is probably as high a proportion of the land surface of Africa mapped in detail and published as there is of the United States. This is due largely to the fact that so few of the published maps of parts of the United States show vegetation and that so few of our maps that do show vegetation are published.

The Principles Followed in the Present Classification

To discuss the vegetation it is necessary first of all to have an adequate classification, and this classification should be based on the vegetation alone. This natural vegetation is an integration of all climatic and soil factors, past as well as present, and therefore the most useful vegetation map is one in which the

vegetational formations or biological units are made the basis of the classification. Other factors may then be measured in terms of vegetation. In the present map (Pl. I) an attempt has been made to base the classification entirely upon the distinctive features of the vegetation itself.

When properly analyzed and classified the vegetation may be interpreted to serve a most practical purpose. The suitability of virgin land for various crops is indicated, and a means is provided for dividing the country into natural regions of plant growth, of use in the development both of agriculture and forestry. (These natural regions are much more significant from an agricultural point of view than are physiographic units, which are so generally used in this country both in the treatment of vegetation and for general geographic discussion.) The classification of the land according to its usableness for agriculture, grazing, and forestry forms the subject represented on Plate II and discussed in Part III of the present work.

Two points have been constantly in view. First, the division into units should be natural and each should have ecological significance. As a consequence they will be valuable in indicating the potentiality of land for crop production. In the second place, the units should be so distinct that they can be easily distinguished in the field; and, because of the nature of much of the data available for drawing such a map, they should be easily recognized from the descriptions of non-technical travelers. An ideal classification is not possible, but an attempt has been made to present a classification indicating the present conditions of the vegetation and to carry this classification as far as the data justify.

In this classification plant associations cannot be shown. We must deal with broader, more inclusive units of vegetation, the plant formation or formation group. Tropical rain forest is a name applied to all the tropical rain forest regions throughout the world, and it is probable that the African tropical rain forest represents, because of its floristic unity, a community distinct from that of the Amazon valley, for example. The climatic

conditions, however, are much the same, and they belong to the same formation group; or, if we use the very broad definition of "formation" employed by many of the European botanists, all would fall within the same formation, the African forest being a subformation. We prefer here to discuss the African tropical rain forest, because of its floristic unity, as a formation which, with the Amazon and other tropical rain forests, constitutes the great world tropical-rain-forest formation group. Within a formation there occur minor communities, the most important of which are the plant associations. A plant association is characterized by a narrow range of environmental conditions and is dominated by distinct floral elements—one or more species—forming a unit of vegetation which can be recognized and described in detail by the botanist in the field.

It is not likely that the geographer untrained in botany would distinguish nearly related associations, for they are based upon specific differentiation, as, for example, the distinction between the grama grass (*Bouteloua gracilis* (H. B. K.) Lag.) association and the black grama (*Bouteloua eriopoda* Torr.) association, or between the shadscale (*Atriplex confertifolia* (Torr.) S. Wats.) association and the sage brush (*Artemisia tridentata* Nutt.) association as they occur in the United States. But in the formations[1] the broader and more distinctive phases of vegetation stand out and are more easily recognized on the basis of the general habit of the plants than are the associations, which often look much alike. It is possible for the explorer, even though untrained in botany, to recognize the formation in the field; and we are here mapping what may be called formations.

Some of the more important species as listed by the various authors are given here, chiefly to give the botanist a better picture of the types. In most cases the species listed are likely to prove the dominants of associations, but so little attention to the dominance of species has been given in many of the

[1] Cf. Charles Flahault and Carl Schröter: Rapport sur la nomenclature phytogéographique, *Actes du 3me Congr. Internatl. Botanique, Bruxelles, 1910*, Vol. 1, pp. 131–162.

botanical descriptions that it is impossible at this time to give a satisfactory list.

In mapping and classifying vegetation we can deal only with the vegetation as we find it, and it would be unsafe to map what we think will be the ultimate stage of vegetation. Surrounding the tropical rain forest is a great savana (a grassland with trees scattered through). If the destruction of forests by primitive man and by fire could be suspended, the forest would undoubtedly spread out over a much wider area. That the forest would ultimately replace all the grassland is very doubtful; but the grasses, by the aid of fire, which is started by lightning as well as by primitive man, extended over portions that could otherwise have developed forests. This is true wherever forest and grassland come in contact. To map the grassland areas which would become forest if fire were eliminated could not be done without a detailed soil survey or years of experimental planting. It is equally possible that if fire were eliminated as a factor the dry forests would be composed of very different species from those found there at the present time. In the use here employed, the term "formation" is not based on habitat but on vegetation.

As one passes southward from the equatorial region of high rainfall (inset map, Pl. II) toward the Namib Desert of Southwest Africa the change from tropical rain forest to absolute desert is as gradual as climatic changes always are where topography is not a decidedly influential factor. Yet the changes are as distinct and great as it is possible to conceive. We pass through the following series of formations in the order named (Pl. I): tropical rain forest; high grass-low tree savana; dry forest; acacia-tall grass savana; acacia-desert grass savana; desert grass-desert shrub; desert shrub; and desert. All of these changes are gradual and are not marked by topographic boundaries. They are the result of decreasing water supply. Going from the same point up the highlands of East Africa we pass from tropical rain forest to temperate rain forest, mountain grassland, and alpine meadow, here correlated with decreasing temperature due to increase in elevation.

Were it not for the vegetation we could not delimit the climatic units which characterize each. For the vegetation indicates clearly in a general way the point at which to draw the division lines. In fact, much advance must be made in our methods of evaluating the physical factors which we term climatic before these can be closely correlated with plant formations, not to speak of plant associations or any of the less extensive plant communities.

Under a given climate, on the broad expanses, the thorn forest may develop as a climatic formation in South or East Africa or south of the Sahara. But in the Sahara, under a climate much too severe for its development, this same type may occur as a result of irrigation or subirrigation (being then an edaphic formation). It may also develop on the light sands of East or South Africa under a relatively heavy rainfall, so heavy that, with a good loam soil, the thorn forest would give way to acacia-tall grass savana or dry forest. Although the water in these cases is supplied in a slightly different manner, and although no climatic analysis would throw them together, they are nearly identical on the basis of water supply and demand and are practically identical on a vegetation basis. By using the vegetation as a criterion we are enabled to make significant analyses of the climatic and soil conditions. To use the habitat as the criterion is in our present state of knowledge of the relation of factors to plant growth all but impossible.

The terminology here used does not conform to that used by European or African botanists, although the grouping is in accord in most cases. This departure is due to the desire to avoid the words "steppe" and "veld." "Veld" has no specific meaning and is applied to all types of vegetation occurring in South Africa. "Steppe" is possibly more physiographic or climatic than botanical and is used to indicate almost any type of vegetation which is affected by drought at some time during the year. "Savana" also is used in so many different ways that it must be described before it can have any specific value. Our attempts to avoid its use have not been successful, and it is

therefore used here to designate a grassland in which trees grow either singly (orchard steppe) or in scattered clumps (park land).

It is difficult to secure terms which characterize the large units of vegetation. If we were mapping associations, specific plant names could be used; but, since we are dealing with formations, the designation should be more general.

In Africa especially the known and unknown areas contrast sharply. In special sections, notably South Africa, the former German colonies, portions of Nigeria, the Anglo-Egyptian Sudan, Morocco, and Algeria, numerous studies and in some cases official surveys make it possible to enter details of distribution. But for the most part the vegetation can be sketched only in broad belts. The reader should not be misled by the differences in detail in different portions of the map (Pl. I). Broad belts of perfectly uniform vegetation seldom exist. In the broad belt of acacia-desert grass savana north of Northern Nigeria there are many thickets of thorn forest, located with the aid of the maps of the British General Staff. This condition probably extends throughout the whole belt, but such areas cannot be shown, since data are not available for their location. They are entered only where the location has been shown on survey or sketch maps or where such areas have been indicated by explorers and travelers. In other words, this is a generalized map in which as much detail has been shown as the data justify.[2]

The Types of African Vegetation

The vegetation of Africa varies from almost absolute desert to the luxuriant tropical rain forest. The intermediate types

[2] The map is based mainly on the text and maps of the publications enumerated in the List of References after Chapter IV. Besides specifically botanical accounts, these include books of travel and exploration and articles in geographical, geological, zoological, and other journals. Not all the material used is listed, however. In many cases papers which give the best information on distribution do not give a detailed description either of the vegetation or agriculture; these have not been cited. Nor have the various separate maps issued by the Geographical Section of the General Staff of the British War Office and by the similar agencies of the French and other governments which were used for their topographical information. The two general references which are given at the bottom of the next page will be of assistance to the reader in securing further data.

can be grouped largely on the basis of their increasing or decreasing water supply. The great highlands which extend across the continent on the eastern side introduce variations in temperature, and to this factor can be attributed largely the occurrence of a grassland (mountain grass), a forest (temperate rain forest), and an alpine meadow type that differ essentially from those which occur on the lower lands of Africa. There are also a temperate forest (oak-conifer) area in the extreme northern portion and a temperate brush land (maqui and Cape flora) in the extreme northern and southern portions which are quite distinct. The low brackish or salt swamps of the coast lands produce a distinct forest (mangrove), while the salt subirrigated areas in the desert and semi-desert areas are characterized by the salt desert shrub. Where fresh water is available in the desert soils oases occur, and where surface water is in excess and swamps are formed the marsh grass type is dominant.

Twenty-one types of vegetation (twenty on the map, Pl. I), have been distinguished. These types may be grouped in nearly concentric rings around the tropical rain forest.

The *tropical rain forest* (Fig. 3) occurs along the west coast from Sierra Leone on the north to the mouth of the Congo on the south and extends eastward in a broad belt, occupying much of the Congo basin. It represents the most luxuriant type of vegetation on the continent, a type developed under abundant moisture supply and with high temperature—a climate in which neither a pronounced temperature nor a drought rest period occurs.

Continuation of footnote 2.

Adolf Engler: Die Pflanzenwelt Afrikas, insbesondere seiner tropischen Gebiete: Grundzüge der Pflanzenverbreitung in Afrika, und die Charakterpflanzen Afrikas. 3 vols. in 4. Vol. 1, Allgemeiner Überblick über die Pflanzenwelt Afrikas und ihre Existenzbedingungen. 2 halves; maps, ills., plates. (Die Vegetation der Erde: Sammlung pflanzengeographischer Monographien, herausg. von A. Engler und O. Drude, Vol. 9) Leipzig, 1910. Especial attention is called to pages xvi–xxviii, where the names of many of the more important botanical workers are given.

Friedrich Hahn: Afrika. *In* Allegemine Länderkunde edited by Wilhelm Sievers. Second edition of "Afrika" by Wilhelm Sievers, Leipzig, 1895. 681 pp.; maps, ills., plates. Leipzig, 1901. Sections E, F, and G on pp. 16–54, and the map and the list between pp. 36 and 37 afford a good survey of African exploration. The works of travel of explorers have yielded the best material on plant distribution for the present work.

Just beyond this type, forming a broad band extending from Senegal to Uganda and across the southern Congo and northern Portuguese West Africa, is the *high grass-low tree savana* (Fig. 16), composed of grass 5 to 12 feet high[3] with scattered bushes and small trees and occasional palms. Trees occur either singly or in clumps, generally clustered about termite hills. Practically every year this region is swept by fire, made possible by a drought period of from one to five months during midwinter.

Passing out from this high-grass area the conditions become more favorable for tree growth and less favorable for coarse grasses. The drought period becomes longer, the rainfall less. Fire still runs through the grass cover, but this does not kill out the relatively tall trees which form the *dry forest* (Fig. 11), an open stand of flat-topped trees with a tall-grass forest floor.

Toward the desert, where the drought period is relatively longer and where there is less total water supply, trees become much more scattered and occur singly or in clumps. This country is characterized by a tall grass 3 to 6 feet high,[4] which forms a nearly continuous cover and is called the *acacia-tall grass savana* (Figs. 20 and 21). It is one of the most extensive plant formations on the whole continent of Africa and forms a great band extending from the Cape region in the south, along the east coast (with a branch across the northern portion of the Kalahari), across the lower portions of the highlands of East Africa, northern Uganda, the Anglo-Egyptian Sudan, and thence westward to Senegal. This type is also prominent in the lower lands of Abyssinia.

Tall grass (Figs. 25 and 26), relatively free from tree and shrub growth, occurs throughout the acacia-tall grass savana, especially at higher elevations in South and in Central Africa. The most extensive area is found in Transvaal and the Orange Free State.

Beyond the acacia-tall grass savana lies the *acacia-desert grass savana* (Figs. 27 and 28). The trees are usually thorn bushes,

[3] The terms "tall grass" and "high grass" are here used to reflect the distinction, clearly evident in the field, between the group of grasses about 3 to 6 feet high and the group 5 to 12 feet or more high.

[4] See footnote 3.

often small and scattered, and the grasses are usually of the desert type, such as bunch Aristidas, which produce a small amount of growth after the rains and remain dormant during the rest of the year. In much of this area there is also developed an ephemeral growth after the rainy period. This type forms a broad belt south of the Sahara and extends around the Abyssinian highland through Somaliland and into East Africa. It occurs again in the region of the Kalahari in South Africa and extends up the west coast into Portuguese West Africa. In this type for the first time the grasses become so small that fires are relatively unimportant. The drought period is long, from five to eight months; and during this period, especially where the number of grazing animals is large, the grass vegetation all but disappears.

Where conditions of moisture supply are a little more favorable, or where the surface soil conditions do not favor the growth of grasses, the thorn trees often form dense thickets or *thorn forest* (Fig. 12). It is similar ecologically to the acacia-desert grass savana.

Another type, not shown on the map, the *desert grass* (Fig. 29), is similar to the acacia-desert grass savana, but free of acacias or other woody growth. Here belong some of the halfa areas of the north and some of the desert-grass regions of East and South Africa. Local areas of this type occur throughout the acacia-desert grass savana and desert grass-desert shrub as marked on the map but cannot be differentiated there because of insufficient data. The desert-grass does not differ greatly ecologically from those types, and the grazing conditions and agricultural potentialities are about the same.

Passing to still lower rainfall and a still longer drought period, we come to the *desert shrub-desert grass* (Fig. 36), differing only from desert shrub in that the areas have greater forage value, largely because of the greater number of grasses (which may be either perennial or ephemeral) occurring during the short rainy period.

In the *desert shrub* (Fig. 37), we pass to what is popularly

known as desert. Although the vegetation is abundant so far as the number of species and of individuals is concerned, the bare ground is always more or less prominent, and, since the plants pass much of the year in a drought rest condition, they attract little attention from the casual observer. The desert shrub occupies areas of low rainfall coupled with long drought periods of from five to eight months or often a year or more. It is usually made up of small woody shrubs but in some places is composed largely of succulents. Grasses, where they do occur, have often a peculiar shrublike appearance. The more luxuriant phases during periods of growth show the most interesting plants known to botanists. Many of these shrubs and succulents are valuable for grazing, but as a rule areas of this type have relatively low carrying capacity.

Extensive areas of absolute *desert* (Fig. 39) from a botanical standpoint do not exist in Africa, but the approach is so close in portions of the Namib of Southwest Africa and in the Sahara that it may well be classified as such. Scant growth, a few herbs and resistant shrubs, or occasionally grasses are found everywhere, at least where an occasional rain occurs, and no area is entirely rain-free. Only the worst portions have been mapped as desert, including the great moving sand areas of the Sahara. The area thus mapped is unproductive either agriculturally or as grazing land.

Where fresh water occurs in desert areas, *oases* (Fig. 15) are formed, and intensive agriculture is always practiced. Some of the more important oases are marked on the map.

Where the water is brackish or the soil of high salt content the *salt desert shrub* (Fig. 38) occurs instead of oases.

If now we pass from the tropical rain forest to a higher elevation, a decided change in the character of forest occurs. The tropical rain forest gives way to the *temperate rain forest* (Figs. 6 and 7), which occupies the highland, especially the mountain sides where clouds rest for long periods and where the rainfall is consequently abundant. This forest occurs on all the higher mountains of East Africa and extends south, where it occurs

at lower and lower elevations until in the Cape Province it practically reaches sea level.

On many of the uplands, especially on the more level mountainous areas, is found the *mountain grassland* (Figs. 30 and 31). The grasses are from 1 to 4 feet high, abundantly supplied with water, and not suffering regularly from drought. This type has a temperate climate and constitutes the most productive grazing land in all Africa.

Lying above timber line on a few of the higher mountains are areas of grassland, rock fields, and ice fields. These have been shown on the map as *alpine meadow.*

In addition there occurs in both South Africa and Mediterranean Africa the *temperate brush* (Fig. 13), known in the south as the Cape flora and in the north as the maqui.

On the highlands of the Atlas Region of North Africa the *oak-conifer forests* (Fig. 10) constitute a type distinct from that of the other portions of Africa. The drier portions of the juniper and olive forests of East Africa probably could be included here as well as with the temperate rain forest. Such areas are limited, however, and cannot be satisfactorily separated from the temperate rain forests, with which they have consequently been grouped.

Small areas of *dwarf palm-temperate grass* (Fig. 33) along the Mediterranean, the *marsh grass* (Fig. 34) covering great swamp areas of the Nile, Congo, and other rivers and lakes in Central Africa, and the *mangrove forests* (Fig. 2) on the tropical coasts complete the brief survey of the vegetation of the continent.

Correlation of Vegetation with Other Distributions

So controlling an element as vegetation, itself largely an expression of climate, naturally exerts a dominant influence on the distribution of life forms. It may, therefore, be of interest to discuss briefly some of these correlations.

NATIVE FAUNA

In a general way these vegetation areas may be correlated with the fauna of Africa. The tropical rain forest has a fauna

distinct from the high grass-low tree savana. In this forest there occur the gorilla, the chimpanzee, and the okapi, together with many arboreal mammals and birds which do not occur in the grassland areas. The high grass-low tree savana areas, on the other hand, have many animals, such as the rhinoceros and many of the antelopes, which do not penetrate the forests. The buffalo and elephant are at home in either the acacia-tall grass savana or the tropical rain forest. The great game centers are in the acacia-tall grass savana, the tall grass, the acacia-desert grass savana, and the desert shrub-desert grass areas. Here occurs a wealth of herbivora: giraffe, zebra, eland, koodoo, oryx, hartebeest, wildebeest, oribi, steinbok, dik-dik, gemsbok, water buck, springbok, gazelle, roan and sable antelope, as well as the ostrich and a large number of carnivora (which feed on the herbivora), such as the lion, leopard, cheetah, jackal, hyena, and hunting dog.

In the temperate rain forest there are bongo, colibus, and black forest hog, while the marsh grass is inhabited by lechee, kob, Mrs. Gray's waterbuck, hippopotamus, reedbuck, and sitatunga. The elephant ranges from desert to tropical rain forest and from sea level to timber line and is often found in the marshes.

Among the smaller and less known animals and birds the correlation of habitat and range is often very close.[5] Probably the most distinct faunal division comes between the tropical rain forest and the high grass-low tree savana.

AGRICULTURE

A brief general survey may also here be made of the agricultural potentialities of the land characterized by each type. This question is discussed in greater detail in Part III of the present work and illustrated by the accompanying land classification map (Pl. II).

[5] J. P. Chapin: Migration of Birds in Africa, *Amer. Museum Journ.*, Vol. 16, 1916, pp. 540–545.

Without mentioning specific crops, the tropical rain forest, especially the alluvial land, will produce tropical crops of grain, sugar, fruits, roots, rubber, oils, and vegetables. Somewhat less productive, but still especially adapted to grains, root crops, and oil crops, is the high grass-low tree savana land. The dry forest and acacia-tall grass savana are suited chiefly to the warm-weather cereals—maize, sorghum, and pennisetum—and root crops such as sweet potato; and the tall-grass area is primarily a maize-producing country. A prolonged drought period makes the last three types much more restricted in fruit and crop production than the other types mentioned above.

The other productive areas are the temperate rain forest, productive of tropical and temperate crops alike; the mountain grassland, similar to the temperate rain forest in crop production but in addition most valuable grazing land; and the temperate-brush land of the Cape and Mediterranean regions, which is productive of temperate fruits and cereals. The dwarf palm-temperate grass areas of the Mediterranean are chiefly cereal producing; and the oases are noted primarily for dates. The other types, desert, desert-shrub, desert shrub-desert grass, and acacia-desert grass savana are, with the possible exception of the last, of no agricultural importance without irrigation. The alpine meadow and mangrove forests are non-productive agriculturally, and the marsh grass areas must be drained before they become suitable for crop production. Great agricultural belts can be recognized, such as the tropical rain forest and the high grass-low tree savana, which are productive principally of banana, cassava, maize, and rice; the dry forest and acacia-tall grass savana and tall grass areas, which are largely devoted to warm-weather cereals (such as maize, sorghum, and pennisetum), peanuts, and cotton; and the temperate rain forest and mountain grassland, which produce primarily bananas, beans, and cereals. The limit of successful dry-land production of agricultural crops comes between the acacia-tall grass savana and the acacia-desert grass savana. In the latter only sorghum, pennisetum, or other drought-enduring crops are grown, and

these are limited to wet seasons or to areas which receive flood water in time of rain.

Domestic Animals

The distribution of domestic animals can also be correlated with the types of vegetation to some extent. Horses are not found in the tropical rain forest or the high grass-low tree savana. Even the tall-grass areas and the dry-forest region are almost closed to horses. The restrictions are due to disease.[6] Camels are limited largely to the acacia-desert grass savana, desert shrub-desert grass, and desert-shrub areas of northern Africa. The great cattle areas [7] are for the most part in the acacia-tall grass savana, although in much of this land disease is a serious handicap. Goats, sheep, hogs, and chickens occur wherever natives live, except that hogs in northern and eastern Africa are shut out by Islamism.

Domestic animals in the tropical rain forest and the high grass-low tree savana are limited largely to goats, sheep, and hogs. Dogs and chickens are found everywhere. As we pass out to the drier type in the acacia-tall grass savana, cattle become the most important class, although the other animals mentioned above are also found. The principal pastoral tribes occur in this zone—the Kaffirs (Swazis, Zulus, etc.), Basutos, Bechuanas, and Hereros in South Africa; the Masai and Gallas in East Africa; and the Nilotic negroes and Fulbes in the north. The South African tribes have the large-horned ox; the Masai and Gallas, small-horned humped cattle; while in the Nile region the large-horned ox is again prized. This is the cattle zone of Africa, and although several pastoral tribes live outside, the greater number are within this area.

The acacia-desert grass savana and desert grass-desert shrub

[6] Some of these are shown on a map of the distribution of germ diseases in Africa affecting man and beast, scale 1:45,000,000, accompanying an article by Sir H. H. Johnston in the *Geogr. Journ.* for April, 1915.

[7] These cattle areas, as well as the grazing and timber lands discussed immediately below, are broadly outlined on a map of the economic resources of Africa, 1:45,000,000, accompanying the same article by Sir H. H. Johnston.

areas of the south are used for cattle, sheep, goats, ostrich, or even horses. It was in this type that the Hottentots, a pastoral tribe, were living for the most part, although they occupied all the desert types as well as the Cape region. In northern and eastern Africa the camel becomes important in this zone. The mountain grassland in Central Africa is occupied by the great cattle-raising Watusi tribe; and cattle, horses, and other domestic stock thrive on this grassland in Abyssinia.

Grazing and Timber Lands

As grazing land the mountain grassland is best, followed by the tall grass and acacia-tall grass savana areas where diseases are not fatal. The dwarf palm-temperate grass land of the Mediterranean, the acacia-desert grass savana, and the desert shrub-desert grass areas are excellent grazing areas of low carrying capacity.

Timber production is probably best in the tropical rain forest and the temperate rain forest, but the dry forest produces small logs with special characteristics of resistance to termites, and the mangrove forest provides wood of great value because of its resistance to termites and, when used in salt water, to wood-boring mollusks.

NATIVE RACES

In a general way the tropical rain forest is occupied mostly by negroes (Bantus); the high grass-low tree savana in the southern Congo, mostly by Bantus. In the north a part of this area and the acacia-tall grass savana and the acacia-desert grass areas are occupied by the Fulbe and, in the Upper Nile region, by the Nilotic negroes; in East Africa the acacia-tall grass savana and the acacia-desert grass areas are occupied by the Gallas and Masai, in South Africa by Bantus, chiefly Kaffirs and Hereros. The mountain grassland is dominated largely by the Hamitic tribes, Gallas and Watusi; while the Cape region, the Karroo, and the Kalahari were largely inhabited by Hotten-

tots and Bushmen. Only on a very broad basis can vegetation be correlated with native tribes.[8]

Approximate Area Occupied by Each Type of Vegetation

In view of the bearing of vegetation on agricultural potentiality, it has been thought well to measure the vegetation areas. This was done by planimeter on the vegetation map when it was in its manuscript form on the scale of 1: 5,000,000. The figures are given in Table I.[9] By grouping these figures, Tables II and III are obtained. Which vegetation areas have been combined to create the groups in these tables is indicated in each case.

The tables bring out the following relationships:

Of the three broad groups into which the types of vegetation here established may be divided, the forests occupy 19 per cent, the grasslands 42 per cent, and the deserts 39 per cent of the continental area (Table II). The 19 per cent of forest land consists of about 17 per cent of timberland and 2 per cent of woodland. Scattered timber is also found in the savana land, which constitutes about 37 per cent of the total area of the continent, while the pure grassland constitutes only 5 per cent.

From the standpoint of agriculture (Table III) 50 per cent is productive land and 50 per cent non-productive. The 50 per cent of productive land consists of 43 per cent suited to tropical and subtropical agriculture and of only 7 per cent suited to temperate agriculture. It is difficult to estimate grazing land, since diseases

[8] A discussion of the native races of Africa will be found in such manuals of ethnology as:

Friedrich Ratzel: Völkerkunde, 2nd edit., 2 vols., Leipzig, 1894–95 (Engl. translation by A. J. Butler, 3 vols., London and New York, 1896; African races discussed in Books 3, 4, and 5 in Vols. 2 and 3).

J. Deniker: Les races et les peuples de la terre: Éléments d'anthropologie et d'ethnographie, Paris, 1900 (English edit.: The Races of Man: An Outline of Anthropology and Ethnography, 2nd edit., London, n. d.).

A. H. Keane: Man, Past and Present. Revised and largely rewritten by A. Hingston Quiggin and A. C. Haddon, Cambridge, England, 1920.

R. B. Dixon: The Racial History of Man, New York, 1923.

[9] Footnote 9 is on p. 20.

TABLE I—AREA OCCUPIED BY EACH TYPE OF VEGETATION IN AFRICA

VEGETATION TYPE	AREA IN SQUARE MILES	PERCENTAGE OF TOTAL AREA
Forest		
Mangrove forest	9,700	0.1
Tropical rain forest	875,000	7.8
Temperate rain forest	52,300	0.5
Oak-conifer forest	19,500	0.2
Dry forest	885,000	7.9
Thorn forest	77,600	0.7
Temperate brush	128,400	1.1
Oases	9,200	0.1
Total forest area	2,056,700	18.4
Grassland		
High grass-low tree savana	1,297,000	11.6
Acacia-tall grass savana	1,785,000	15.9
Tall grass	99,400	0.9
Acacia-desert grass savana	1,074,000	9.6
Desert grass (included in preceding)		
Mountain grassland	363,000	3.2
Alpine meadow (included in preceding)		
Dwarf palm-temperate grass	76,000	0.7
Marsh grass	42,000	0.4
Total grassland area	4,736,400	42.3
Desert		
Desert shrub-desert grass	1,220,000	10.9
Desert shrub	2,300,000	20.5
Salt desert shrub	4,900	0.0
Desert	882,000	7.9
Total desert area	4,406,900	39.3
Total land surface (without lakes)	11,200,000	100.0

play so important a part. But one may estimate the total area suitable for grazing of disease-resistant stock such as sheep and goats as 83 per cent of the continent. This includes the browse

[9] Figures derived from a similar measurement of the vegetation areas outlined on Paul Langhans' Wandkarte von Afrika zur Darstellung der Bodenbedeckung, 1 : 7,500,000, Gotha, 1906, may be cited here. The figures are given in Hermann Wagner: Lehrbuch der Geographie, 9th edition, Hanover, 1912, p. 724, footnote 8. For comparison with Table I the areas have been transformed into square miles, and the figures for the relevant vegetation types have been reduced by the exclusion of Madagascar and the other African islands, as these are not included in our tabulation. The corresponding types of vegetation in our tabulation, in so far as they lend themselves to comparison, have been indicated by their symbols as they appear on the map, Pl. I.

AREAS OCCUPIED BY VEGETATION TYPES ON LANGHANS' MAP

Vegetation Type	Approximate Equivalents on Pl. I	Area in Square Miles	Percentage of Total Area
Compact tropical forest (Guinea and equatorial forest)	*FF*	748,000	6.6
Tree and bush savana, with gallery forests, and forests and cultivated land of the temperate zone and oases	*D, ss, s, F, C, T, B, O*	4,715,000	41.9
Open grassland without trees	*g,m, p*, part of *s,a*, and of *Dg*	1,103,000	9.8
Steppe, with periodic plant growth (steppe grasses and bushes)	*a,Dg, Db*	2,664,000	23.6
Sand dunes	*Dd*	927,000	8.3
Sandy and stony desert, salt steppe	*Ds*, part of *Db*	1,043,000	9.2
Lakes		67,000	0.6
Total area without islands		11,267,000	100.0

of such areas as the Karroo and the Cape region. Cattle even on this broad basis would be limited to less than 63 per cent of the continental area, while about 24 per cent may be classed as good grazing for cattle. Much of this land has a very low carrying capacity, probably the equivalent of one cow to twenty acres or less.

TABLE II—AREA OCCUPIED BY THE MAJOR SUBDIVISIONS OF THE THREE GREAT GROUPS OF VEGETATION TYPES OF AFRICA

SUBDIVISION	AREA IN SQUARE MILES	PERCENTAGE OF TOTAL AREA
Forest		
Timberland*	1,841,500	16.5
Woodland†	215,200	1.9
Grassland		
Savana‡	4,156,000	37.1
Grassland§	580,400	5.2
Desert		
Desert	4,406,900	39.3
Total land surface (without lakes)	11,200,000	100.0

* Mangrove forest, tropical rain forest, temperate rain forest, oak-conifer forest, dry forest.

† Thorn forest, temperate brush, oases.

‡ High grass-low tree savana, acacia-tall grass savana, acacia-desert grass savana.

§ Tall grass, mountain grassland, dwarf palm-temperate grass, marsh grass.

TABLE III—AREA OCCUPIED BY EACH TYPE OF AGRICULTURAL LAND IN AFRICA

TYPE OF AGRICULTURAL LAND	AREA IN IN SQUARE MILES	PERCENTAGE OF TOTAL AREA
Grazing land		
Suitable for sheep and goats, including browse of low carrying capacity*	9,247,300	82.5
Suitable for sheep and goats, better grazing land only†	5,707,800	50.9
Suitable for cattle‡	2,633,300	23.5
Agricultural land		
Tropical and subtropical§	4,851,200	43.3
Temperate‖	738,600	6.6
Total agricultural land	5,589,800	49.9
Non-Agricultural land	5,610,200	50.1
Total land surface (without lakes)	11,200,000	100.0

* Oak-conifer forest, dry forest, temperate brush, high grass-low tree savana, acacia-tall grass savana, tall grass, acacia-desert grass savana, mountain grassland, dwarf palm-temperate grass, desert shrub-desert grass, desert shrub.

† The same, less oak-conifer forest, desert shrub-desert grass, desert shrub.

‡ Temperate brush, tall grass, acacia-desert grass savana, mountain grassland, dwarf palm-temperate grass, one-half the area of acacia-tall grass savana.

§ Tropical rain forest, dry forest, oases, high grass-low tree savana, acacia-tall grass savana.

‖ Temperate rain forest, oak-conifer forest, temperate brush, tall grass, mountain grassland, dwarf palm-temperate grass.

CHAPTER II

THE FORESTS

We shall now take up the detailed description of the vegetation types. Of the three broad groups into which these types may be divided, we shall discuss the forests in this chapter. The grasslands will form the subject of Chapter III and the deserts of Chapter IV.

Mangrove Forest

Fig. 2; *M* on map

The mangrove forest is a low, coastal swamp forest of trees 25–75 feet high, standing on high, arched prop roots, which lift the main stem of the tree above high tide. The tops extend down to near the water level at high tide. The crowns are relatively dense, with deep green evergreen leaves. At low tide the lower portion presents an almost impenetrable tangle of roots and knees, often covered with algae and abounding in marine invertebrates. In the waterlogged saline mud, rich in organic matter, aeration is difficult, and many of the mangrove plants also develop respiratory roots. Some are upright, unbranched, a foot or so in height, arranged, as in the case of Avicennia and Sonneratia, along the roots; others are kneelike, as in Bruguiera and Lumnitzera. Another characteristic of many of the species of this forest is the growth of the seeds while still attached to the parent tree. By the time the fruit is ready to fall the seedlings are already fully formed.

(Karsten, Schimper)

BOTANICAL DESCRIPTION

This forest consists of a relatively small number of species. On the east coast (Engler 1895, pp. 6–11) [1] it consists chiefly of

[1] Throughout Chapters II, III, and IV references are thus indicated by the author's name alone, or with the date in addition where more than one of his publications are listed. The titles of publications will be found under the author's name in the List of References following Chapter IV.

Rhizophora mucronata Lam., *Ceriops candolleana* Arn., *Avicennia officinalis* L., *Lumnitzera racemosa* Willd. Somewhat less prominent are *Bruguiera gymnorrhiza* Lam., *Sonneratia caseolaris* (L.) Engl., and *Xylocarpus obovatus* A. Juss. On the west coast the following species are prominent: *Rhizophora mangle* L., *Avicennia nitida* Jacq., *Laguncularia racemosa* Gaertn., and *Conocarpus erectus* Jacq. (Engler 1910, p. 938).

DISTRIBUTION

Forests of this type are confined to swamps in salt or brackish water, mostly at the mouths of rivers and in estuaries. They extend from the Red Sea (Hartmann, Floyer) to Natal (T. R. Sim 1910, Bews 1909–13) on the east coast, and on the west coast from Senegambia (Gruvel) to Portuguese West Africa. Usually these forests are not extensive and are limited to rather narrow belts along protected portions of the coast, to low islands, and the lower saline banks of the rivers. According to Bindloss (p. 138) they compose two-thirds of the Niger delta.

CLIMATIC CONDITIONS

Over much of the area the climate is damp and hot. Rainfall is not a factor in the development of this forest, since it grows entirely upon land flooded by sea water at high tide.

SOIL CONDITIONS

The soil is usually rich in organic matter—a deep, black, saline mud.

NATURAL PRODUCTION

As a habitat for animal life the mud in which the mangrove grows teems with invertebrates. Primitive man found the wood of the mangrove valuable because of its keeping qualities, especially when used in salt water. Civilized man, besides using the wood for construction purposes where termites or mussels attack other woods, also uses great quantities of mangrove bark as tanning material. The east coast furnishes most of the tan-

FIG. 2.—Mangrove forest (*Rhizophora mucronata*). Shows dense foliage and prop roots, also the respiratory roots of *Avicennia officinalis*. At low tide. Tanganyika Territory, April 11, 1920.

FIG. 3—Tropical rain forest. Shows large trees, smaller, second-story trees, lianas, and rather dense growth of Marantaceae on forest floor. The density of the forest canopy is illustrated by the fact that the time required for this photograph was 15 minutes with a Goerz-Dagor lens stopped to 8, or about 20,000 times the normal exposure in the open. Kinda, Belgian Congo, Jan. 28, 1920.

bark, since here mangrove bark is easily prepared for market; while on the west coast the more humid conditions make the preparation of the bark for market more difficult.

AGRICULTURE

This land is entirely unsuited for agriculture.

Tropical Rain Forest

(Equatorial Forest)

Fig. 3; *FF* on map

The tropical rain forest consists of large trees approximately 125 feet high, with a relatively dense canopy. It is by no means a single-storied forest, since there is often an under story of small trees. Lianas are relatively abundant but do not add much to the general appearance of the forest. The undergrowth is dense enough to prevent a distant view except along stream beds, where the forest is often more open. Where it is less dense there is a thick growth of herbs on the forest floor. Many trees, especially *Cynometra alexandri*, stand on prop roots several meters high.

Usually one can proceed without following paths. Flowers are not noticeably abundant; in fact the general appearance is green (foliage) and gray (trunks), and the light is very subdued. The time required for a photograph (Fig. 3) was 15 minutes with a Goerz-Dagor lens stopped to 8, or about 20,000 times the normal exposure in the open.

Although the forest may appear monotonous in places, there is at times an almost endless variety. This is especially true where the land becomes more swampy, when palms and rattan develop.

Along the Liberian-French boundary this forest (Ollone 1901) covers flat and hilly country equally. Rivers form open avenues through the trees, which are 60–80 meters in height. Bombax and Calicedra form the first branches at 50 meters from the ground.

BOTANICAL DESCRIPTION

Mixed vegetation is the rule, but often the forest is dominated by *Cynometra alexandri* C. H. Wright or by *Macrolobium dewevrei* Wildem. or by *Berlinia ledermannii* Harms (Mildbraed 1914, p. 675, Engler 1908, p. 833).

Bertin (1920, pp. 271–273) speaks of the heterogeneous nature of the forest and compares the forests of three regions as in the following table.

PERCENTAGE OF AVAILABLE TIMBER IN THREE REGIONS OF THE TROPICAL RAIN FOREST IN AFRICA

SPECIES	IVORY COAST	GABON	CAMEROONS
Klainedoxa sp.	...	13.0	...
Aucoumea klaineana	...	16.0	...
Desbordesia spp.	6.0	6.5	5.0
Eriodendron guineense	5.5	3.5	6.0
Mitragyna macrophylla	10.0	0.9	0.3
Piptadenia africana	7.0	...	...
Chlorophora excelsa	3.0	0.8	0.3
Parinarium tenuifolium	3.0	...	...
Erythrophloeum guineense	2.5	1.5	5.0
Uapaca spp.	5.0	0.2	2.0
Calpocalyx klainei	...	2.5	0.1
Piptadenia spp.	...	3.0	3.5
Khaya spp.	1.0	0.8	0.7
Sarcocephalus spp.	...	0.8	3.0
Vitex pachyphylla	...	2.5	...
Staudtia gabonensis	...	2.0	1.3
Haematostaphis barteri	2.5	...	...
Lophira procera	4.0	0.6	16.0
Coula edulis	1.0	2.0	3.0
Sarcoglottis gabonensis	...	4.5	7.0

Under certain conditions revegetation is very rapid when the primeval forest is destroyed, but the forest trees which first appear are not of the final stage. The species of this secondary forest have been mentioned by a number of writers. According to Büsgen (1910) the trees of the secondary forest are *Musanga smithii* R.Br., *Ceiba pentandra* (L.) Gaertn., *Rauwolfia macrophylla* Stapf, *Elaeis guineensis* Jacq., and Raphia. In southern Togo (Busse 1907) *Ceiba pentandra* (L.) Gaertn., *Chlorophora excelsa* (Welw.) Benth. & Hook., *Spathodea campanulata* Beauv., and *Elaeis guineensis* Jacq. are prominent in the secondary forest, while in the Cameroons where the forest thins out *Ceiba pentandra* (L.) Gaertn., *Chlorophora excelsa* (Welw.) Benth. & Hook., and *Spathodea campanulata* Beauv. occur (Faber).

(Büsgen 1920, Rendle 1913, Thonner 1899, 1910, Wildeman 1913)

DISTRIBUTION

This forest is not as extensive as one might suppose. In area it covers only a part of the Belgian Congo and of French Equatorial Africa and the southern part of the Cameroons, and occurs only in relatively small isolated areas between the Cameroons and Liberia, where a relatively large area occurs. There are a few small forests east of the Lake Albert-Lake Edward-Lake Kivu rift valley; but for the most part they are on alluvial soil, in all cases are not of wide extent, and if not exaggerated on the map would be almost lost to the eye.

(Bertin 1918, 1918a, 1919, Breschin, Bruel, Büsgen 1910a, 1920, Chevalier 1909d, Fyffe, Götzen, Guggisberg, Güssfeldt *et al.*, Jentsch, N. C. McLeod, A. Moloney, Passarge 1909–10, Ritter, Thompson 1910, 1910a, Unwin 1909, 1920, Whitlock, K. Zimmermann *et al.*, M. Zimmermann.)

CLIMATIC CONDITIONS

The climate is warm and humid. The rainfall ranges from 60 to 160 inches (inset map, Pl. II). Over most of the Congo

forest it is slightly above 60 inches and only in the region of the Cameroons and Liberia does the high rainfall occur. The distribution is relatively uniform throughout the year, and the drought period is lacking or is short, usually not exceeding two months, and is not sufficient to cause leaf fall (Knox).

SOIL CONDITIONS

The soil is, as a rule, relatively fertile. In certain portions, especially the lower areas where the land is alluvial in character, the soil is a rich deep loam; and in the more typical forest areas the deep red forest loam is often lateritic. Native fields, however, have ash and organic matter mixed into the surface, and the soil produces excellent crops.

NATURAL PRODUCTION

Animal life is rather abundant. The constant call of hornbills and the patter of red-tailed gray parrots, the bark of baboons and chatter of monkeys, and the occasional rumble of a buffalo herd keep one more or less constantly on the alert. Here is also a great reserve of bird and animal life. Elephant, okapi, buffalo, and warthog constitute the chief large species except along the rivers, where hippopotami and crocodiles abound.

Primitive man, with the possible exception of the nomadic pygmies, has destroyed portions of the forest, especially along the great waterways. Of the native plants he has found the oil palm, occurring usually along the river courses (Fig. 35) and at the edge of the great forest, one of the most valuable. It furnishes oil prized for food; the oil is also used by him to smear his body and to make soap to wash his clothing. Both the nuts and oil are exported. Rubber secured from the native Landolphia and Funtumia species was until recently an important export commodity. The kola nut is also used extensively by natives, as are also many other natural forest products, among which should be mentioned raffia, used extensively in rug and basket making and as an export product.

The natural products of this forest are many. There is an

FIG. 4.—Tropical rain forest. A native plantation. The underbrush is cut out and burned and the land prepared with the hoe. The plantation shows banana, manioc, and rice. Maize has just been harvested. Kindu, Belgian Congo, Jan. 27, 1929.

FIG. 5.—Tropical rain forest. Coffee plantation at mission grounds. Native village and remnant of forest shown in the background. Kindu, Belgian Congo, Jan. 28, 1920.

immense reserve of timber, probably inferior for general purposes to that of temperate regions, but rapid-growing and of almost endless supply.

(Bertin 1920, Breschin, Büsgen 1910, 1920, Busse 1907, Chevalier 1909, 1912, Jentsch and Büsgen, Thompson 1910.)

At the edge of the forest along rivers and swamps the oil palm, *Elaeis guineensis*, is one of the most important economic plants. Occasionally the trees are very dense, and Daniel (p. 191) estimates as many as 125 per hectare in Dahomey. The importance of the oil palm is emphasized by every writer who visits productive sections of Africa. It is by no means the only important natural product. Ollone (1901) mentions oil palm, mahogany, gum, kola, and rubber. Sir H. H. Johnston (1905, pp. 135–136) for Liberia names as of economic importance *Landolphia owariensis* Beauv., *Funtumia elastica* (Preuss.) Stapf, *F. africana* (Benth.) Stapf, *Coffea nudiflora* Stapf, *C. ligustrifolia* Stapf, and Liberian coffee (*Coffea laurentii* Wildem.). Chevalier (1912, p. 501), speaking of the forests of the Gabon, mentions an inexhaustible wood supply, also a rich supply of oil, kola, rubber, and raffia, and lists (1909, p. 215) among the West African trees which produce oil:

African nutmeg . . . . . *Pycnanthus* sp.
Kombo . . . . . *Dumoria heckeli* Cheval.
Butter tree . . . . . *Pentadesma butyracea* Sabine
Tama de forêt . . . . . *Pentadesma leucantha* Cheval.
Méné de forêt . . . . . *Lophira procera* Cheval.
Oil palm . . . . . *Elaeis guineensis* Jacq.

and as important rubber plants:

Funtumia elastica (Preuss.) Stapf (in forests only)
Landolphia owariensis Beauv.
Clitandra elastica Cheval.

To the rubber, kola, oil, raffia, timber, and other forest products must be added ivory from the elephant herds which inhabit the forests.

Land of this type is not adapted to grazing by domestic animals and in its natural state supports only such animals as the elephant, buffalo, wild hog, okapi, and a large arboreal fauna of monkeys, squirrels, and birds.

AGRICULTURE

When the land is cleared, or a few of the larger trees are cut out and the undergrowth is cut and burned away, it becomes most productive agricultural land.

All travelers in the tropical forest region have recorded the agriculture of the natives, for it is largely by agriculture that they live and support their goats, pigs, and chickens.

> (Adolf Friedrich, Chevalier 1909a, 1912, Daniel, Dudgeon, Esch, Gray and Dochard, Hinde, H. H. Johnston 1906, 1908, Machat, Newland, Ollone 1901, Sarolea, Sprigade, Unwin 1909, Wohltmann, K. Zimmermann *et al.*)

The following crops are grown and are mentioned by travelers in all parts of this area:

Rice	Beans	Mango
Bananas	Tobacco	Guava
Manioc	Peanuts	Annona
Maize	Sesame	Pineapple
Sugar cane	Ginger	Castor bean
Sweet potatoes	Cotton	Vanilla
Oil palm	Orange	Cucurbits
Yams	Citron	

and, in addition to the above, vegetables of all kinds.

Although primitive man in this forest utilizes the natural products, he is still largely agricultural. In the region about Kindu on the upper Congo River, as in other parts of this great forest, he cuts down all but a few of the larger trees and with the aid of fire and the hoe prepares the soil to receive his crop. On this land he plants bananas, relatively far apart, and also

manioc. He then puts in a crop of maize and a little later a crop of upland rice. The maize is harvested just before the rice begins to head. Thus two perennial and two annual crops are grown together (Fig. 4). This area will first become a manioc thicket in about three or four years, yielding a constant supply of this most useful food up to the fourth year, when it is dug out. Later the same area will become a dense banana field. It will continue in this condition until replaced by an early stage in the secondary succession, leading to the re-establishment of the primitive forest. Many other crops are grown by the native, among which may be mentioned sweet potatoes, yams, beans, peas, cucurbits, tobacco, sugar cane, eggplant, tomatoes, and many of our vegetable crops. The native seldom relies on a single crop. There are usually many crops grown together, such as the four just mentioned; or manioc, maize, beans, and peanuts; or voandzeia, sweet potatoes, cucurbits, tomatoes, and eggplant are stuck in almost anywhere; while sugar cane and tobacco occupy small areas often to the exclusion of any other crop.

This area has not been developed by civilized man. Where attempts have been made the following crops are grown: coffee (Fig. 5), citrus fruits, Brazilian rubber, cacao, manioc, maize, and cotton. Almost any tropical crop can be grown here.

CROP POTENTIALITIES

As shown by the actual production by natives and Europeans almost any tropical crop and many temperate crops may be grown on land characterized by this forest. Cacao, rubber (both Ceará and Pará), sugar cane, vanilla, ginger, rice, manioc, yams, sweet potatoes, potatoes, bananas, coconut (near the coast), coffee, arrowroot, indigo, maize, sorghum, pennisetum, eleusine, cotton (where rainfall is not too continuous), peanuts, voandzeia, sesame, oil palm, pineapple, papaya, annona, jack fruit, and tropical fruits and vegetables may be grown.

Temperate Rain Forest

(High Forest, Cloud Forest)

Figs. 6 and 7; *F* on map

The temperate rain forest consists of tall white-trunked, smooth-barked trees (Fig. 6), often with buttressed bases. It is more dense than the tropical rain forest and presents a greater variety of vegetation on the forest floor. Ferns, mosses, epiphytes and vines, and a rich display of flowering plants of various sorts form a dense undergrowth. Flowers are, however, relatively inconspicuous on the forest floor. One is impressed by the tall white trunks of figs and leguminous trees, the dense under verdure of Afrimomum, and the rich tropical foliage of the banana along the streams (Fig. 7). The forest differs greatly at different elevations and with varying rainfall. At times, especially along the upper edge, it contains bamboo thickets which are almost impenetrable, while along the lower and drier edge it may be made up largely of cedar and olive. Even here the undergrowth is abundant, and vines are often an important feature. It is one of the most varied and interesting forests on the continent of Africa.

BOTANICAL DESCRIPTION

This forest is probably best characterized by Podocarpus, of which several species are found: *Podocarpus usambarensis* Pilg. (Meyer 1913, p. 43), *P. elongata* L'Hér., and *P. thunbergii* Hook. (Bews 1909–13, p. 302, Marloth 1905, p. 590). *Olea laurifolia* Lam., *Celtis kraussiana* Bernh., and *Curtisia faginea* Ait. (Bews 1909–13, p. 302, Legat) are important in South Africa, and farther north *Juniperus procera* Hochst. occurs on the drier edge of forest (Hutchins 1909, p. 13, Schweinfurth 1894). In Usambara (Engler 1894, p. 68) *Podocarpus falcata* R. Br. and *Olea chrysophylla* Lam. and in the highlands of Central Africa (Meyer 1913, p. 42) *Olea hochstetteri* Baker, *Macaranga kilimandscharica* Pax, and *Hagenia abyssinica* J. F. Gmel. are important in this forest. In the Mount Ruwenzori region (Mildbraed 1914, p. 660) *Podocarpus*

FIG. 6—Temperate rain forest. A general view. Shows the characteristic large, tall, white trunks. Near Chuca, Kenya Colony, June 17, 1920.

FIG. 7—Temperate rain forest. Detail of interior of forest. Shows rich growth of wild banana and vines. Near Embu, Kenya Colony, May 3, 1920.

milanjiana Rendle and *Hagenia abyssinica* J. F. Gmel. are important. The upper timber line is often formed of the bamboo, *Arundinaria alpina* Schum. (Engler 1910, p. 140), and there are many interesting plants, especially the arborescent species of Senecio, Lobelia, and Erica (Meyer 1900, Volkens 1897, De Filippi).

Much of this temperate rain forest has been destroyed by the natives in order to prepare the land for agriculture. After a few years the land is abandoned and reverts rapidly. The reversion is often not allowed to become complete, and the temporarily abandoned areas are again put under cultivation. The result is the formation around these forest areas of immense tracts of what may be called brush land, dominated at times by bracken (*Pteridium aquilinum* (L.) Kuhn.). Meyer (1900) gives *Myrica kilimandscharica* Engl. and *Agauria salicifolia* Hook. as important species which characterize the secondary succession leading to the re-establishment of the forest.

(Blackburne-Maze, Decken, Hassert 1908, Hutchins 1893, 1905, 1907, 1909, Jaeger 1909, 1911–13, H. H. Johnston 1886, Passarge 1909–10, Purvis, Schoenland 1920, Trotha, Union of South Africa)

DISTRIBUTION

This forest occurs on the high mountains of Central and East Africa and along the mountain ranges at lower and lower elevations as one proceeds south. In the Cape Province it practically reaches sea level (Marloth 1908, p. 61). In the north it occurs throughout the Abyssinian plateau, and a forest which corresponds to it also occurs in the higher mountains of West Africa (Chevalier 1909, p. 215) and in the Cameroons. On Kilimanjaro Meyer (1900, p. 75) describes this type of forest from 1,800 to 3,000 meters.

It is impossible with our present knowledge of distribution to separate entirely the mountain grassland from the temperate rain forest, and areas which are shown on the map as mountain grassland may often contain remnants of this temperate rain

forest, especially in the more protected ravines and on the steeper mountain sides.

CLIMATIC CONDITIONS

The temperature is unusually moderate. High temperatures are seldom recorded, and throughout most of the area frosts never occur. Rainfall varies greatly and ranges from 40 to 80 inches; there is no prolonged drought period.

Fire has been one of the chief agencies employed by primitive man to destroy this forest in preparing the land for crop production.

SOIL CONDITIONS

The soil which underlies this temperate rain forest is probably as productive as any in Africa, with the possible exception of the alluvial bottom lands. It is a fresh red loam, of very complex mineral composition, usually presenting little or no profile.

NATURAL PRODUCTION

This forest has provided food for wild animals, of which the most prominent is the elephant, still found in large numbers in these temperate forests, often in the bamboo thickets near the upper limit of trees. In the region of Mount Ruwenzori the gorilla is found. Among the more important large animals which find here a habitat favorable for their existence are the elephant, bongo, colibus, and black forest hog.

Primitive man as a rule has not found this forest area in its natural state a suitable habitat. A few of the weaker hunting tribes have been driven into these forests and are able to exist in relatively small numbers. The virgin forest is not favorable to dense population, since it produces only a small quantity of vegetable food and is not densely inhabited by animals.

The temperate rain forest furnishes many products which can be utilized by civilized man. Chief among these is timber, which,

FIG. 8—Temperate rain forest. A general view. Shows forest about the falls at the right and land cleared and planted at the left. Also shows brushland. Fields small, on steep hillsides of about 25° to 30° grade, and separated by crude fences. Crops are pennisetum, sweet potato, sorghum, etc. Near Embu, Kenya Colony, May 3, 1920.

FIG. 9—Temperate rain forest. Mixed cultures: maize, rice, sugar cane, banana, manioc, and yams. Moshi, Tanganyika Territory, April 12, 1920.

however, is not of the best quality. In places a considerable amount of rubber is produced. Ivory is also secured from the elephant herds.

AGRICULTURE

Primitive man by destroying the forest has developed these areas into a high state of agricultural production (Figs. 8 and 9). Where the trees are cut or burned down the prepared land produces some of the more important grain crops of Africa. Sorghums, maize, pennisetum, and eleusine are staple crops. Pennisetum is much more generally grown in these temperate forest areas about Mount Kenya than at lower levels. No crop is more important than the banana, which often forms a great zone in the lower part of the great forest belt. Many varieties are grown and used both as a fruit and as a vegetable. The banana is also used extensively in the production of native beer. Yams are more extensively grown about Mount Kenya than at lower elevations. Among the other important crop plants may be mentioned the sweet potato, peanut, voandzeia, bean, pigeon pea, cowpea, tobacco, potato, colocasia, pumpkin, squash, castor bean, and a great variety of vegetables.

Agriculture is practiced by the natives entirely with the hoe. The slope of the land is therefore not considered (Fig. 8). A characteristic view would show steep mountain sides with small patchwork fields of maize, pennisetum, eleusine, sweet potatoes, or sorghum, beans or pigeon peas, or dense groves of bananas and yams. In each grainfield is a platform from which the crop is protected from birds. Often these fields occupy large areas in an almost continuous tract, but the area devoted to each crop is seldom more than a few rods across. Banana groves are more often on the uplands or ridges, while the alluvial areas are generally devoted to sugar cane or rice. Fields of sweet potatoes and yams are allowed to continue for a long time, the tubers being removed one at a time as they become large enough to eat.

A relatively small amount of land of this type has been put

under cultivation by the European. The absence of large areas of land tillable by machinery has, however, prevented the European from using more of this land, notwithstanding its exceedingly high fertility. At the present time coffee is one of the most promising crops, although flax and temperate cereals and temperate and subtropical fruits and vegetables can be produced.

(Ainsworth, Bieber, Blundell, Carpenter and Holm, Decken, Ferret and Galinier, Fischer, Fuchs, Goetze, Grogan, Hassert 1917, Hore, H. H. Johnston 1895, Kenya Colony, Leverson, Macdonald and Austin, Mackinder, Neumann, Passarge 1909–10, Pringle, Rohlfs, Roosevelt and Heller, Schweinfurth 1869–71, Sclater, Stuhlmann 1894, 1909, Trotha)

CROP POTENTIALITIES

The following crops may be grown: temperate crops such as wheat, barley, oats, rye, potatoes, lucerne, clover, and flax; also crops of beans, peas, pigeon peas, cowpeas, soy beans, tomatoes, tobacco, maize, sorghum, millet, rice, pennisetum, peanuts, voandzeia, yams, and sweet potatoes. Many fruit trees which are being grown may be mentioned, such as the apple, pear, peach, plum, apricot; also orange, nectarine, tangerine, lemon, lime, and grapefruit. Wattle can also be produced. No portion of the world is better adapted to the production of bananas and coffee.

Oak-Conifer Forest

Fig. 10; *C* on map

On the high land in the mountain region adjacent to the Mediterranean, there occur forests of conifers and oak. These forests are, as a rule, relatively open; and the trees are of rather small size. In appearance this forest differs remarkably from all other forests in Africa, and is of decidedly temperate character, with undergrowth consisting of low grasses.

FIG. 10—Oak-conifer forest. General view of cedar forest (*Cedrus libani var. atlantica*) in southern Constantine Province, Algeria. (From Rikli, Schröter, and Tansley, *Vegetationsbilder*, Ser. 10, No. 1–3, Section 2, Pl. 14.)

Fig. 11—Dry forest. A general view. Shows open grass floor with a few small trees. Forest trees far apart, not casting a dense shade. Elizabethville, Belgian Congo. Dec. 28, 1919.

BOTANICAL DESCRIPTION

The forest is composed largely of *Cedrus libani* Barrel., *Pinus halepensis* Miller, *Quercus lusitanica* Lam., *Quercus ilex* L.

(Bernard and Ficheur; Hagen; Marc and Kuss; Rikli, Schröter, and Tansley; Trabut 1888)

DISTRIBUTION

This forest is limited to the higher elevations along the Mediterranean, occurring chiefly in Morocco, Algeria, and Tunis.

CLIMATIC CONDITIONS

Rainfall is moderate, ranging from 20 to 35 inches, and the drought period ranges from three to five months in midsummer.

SOIL CONDITIONS

The soil is generally free from hardpan, low in organic matter, and well leached.

NATURAL PRODUCTION

The principal products of this area are cork, tanbark, timber, and, in the more open portions, pasturage. The principal crops that can be grown are olives and grapes, especially at the lower altitudes, and temperate cereals—wheat, barley, oats, and rye, also maize, sorghum, tobacco, and alfalfa.

Dry Forest

(Miombo Forest, Tree Steppe)

Fig. 11; *D* on map

The dry forest varies in density from an open parklike growth of trees to a relatively dense stand. At no time are the grasses entirely replaced in the substratum. As a rule there are few shrubs or young trees. The diameter of the trunk is seldom over one foot, and the foliage is supported only on the upper part. It is a forest made up largely of flat-topped trees, and one can generally see through it from 100 yards to half a mile. The grass

cover is not dense and consists of relatively tall grasses forming a rather open cover.

Scattered throughout this forest there are many prominent termite hills of various sizes. In many cases the older hills reach a height of 15 to 25 feet. The larger and older hills are usually covered with a heavy, dense growth of vegetation consisting usually of trees, ferns, and flowering herbs.

During the drought period fires sweep through this forest, burning the grasses and destroying the smaller shrubs and trees.

Probably as a result of the rapidity with which wood is destroyed by termites one seldom sees fallen trunks, and the whole presents the appearance of a very closely planted park or orchard in which the limbs of the trees meet overhead but do not form a dense canopy.

BOTANICAL DESCRIPTION

The trees which form this forest are practically the same as those which occur in the acacia-tall grass savana. Among the more abundant are the following:

Berlinia baumii Harms
Burkea africana Hook.
Baikiaea plurijuga Harms
Brachystegia randii Baker
Copaifera mopane J. Kirk
Copaifera coleosperma Benth.
Pseudolachnostylis maprouneaefolia Pax
Diospyros mespiliformis Hochst. (*D. senegalensis* Perr.)
Strychnos schumanniana Gilg
Pterocarpus erinaceus Lam.
Pterocarpus angolensis DC.
Strychnos pungens Solored.
Combretum arbuscula Engl. & Gilg
Brachystegia spicaeformis Benth.
Acacia kirkii Oliver
Zizyphus mucronata Willd.

Terminalia sericea Burch.
Bauhinia reticulata DC.
Acacia nigrescens Oliver

The following grasses, identified by Agnes Chase in the Bureau of Plant Industry of the U. S. Department of Agriculture, were collected by the writer at Elizabethville and Sakania in the Katanga region of the Belgian Congo and are typical of the grass flora:

Alloteropsis semialata (R. Br.) Hitchc.
Brachiaria serrata (Spr.) Stapf
Eragrostis chalcantha Trin.
Thyrsia sp.
Peltophorus sulcatus Stapf
Hyparrhenia rufa (Nees) Stapf
Digitaria uniglumis major Stapf
Brachiaria brizantha (Hochst.) Stapf
Panicum madagascariense Spreng.
Setaria sp.
Setaria aurea Hochst.
Tricholaena rosea Nees
Trichopteryx gigantea Stapf
Trichopteryx gigantea gracilis Rendle?

In species this forest is not especially rich.

(Baum, Burtt-Davy 1905–06, Busse 1900–01, Dove 1903, Engler 1900, 1906, Fries 1913, 1921, Gibbs, Meyer 1913, Neave 1910, Seiner 1909, 1910, 1912, 1913, J. Sim)

DISTRIBUTION

The greatest area of dry forest lies in the south-central portion of the continent and extends in a broad belt from the interior of Portuguese West Africa across Northern Rhodesia, with northward extensions in the southeastern Belgian Congo and the western portion of Tanganyika Territory and a southeastern extension in northern Bechuanaland Protectorate.

It is undoubtedly much more extensive than shown on the map. Relatively small areas only have been shown in the Sudan, but there are many places throughout the Anglo-Egyptian Sudan where the trees become dense enough to form this dry forest type, and undoubtedly this type is likewise important throughout the whole area south of the Sahara. There are many places in the acacia-tall grass savana in southeastern Africa in which the trees are dense enough for the areas to be included in the dry forest as here described. In most cases these cannot be indicated on the map, however, because of insufficient knowledge of the local distribution.

CLIMATIC CONDITIONS

This forest has developed in a region which has a relatively long drought period, four to six months in midwinter. The rest period is entirely due to drought. During this rest period fires sweep through the grass cover, and only such trees as can withstand grass fires are able to maintain themselves. The rainfall varies from about 30 to 40 inches and comes during the growing period.

SOIL CONDITIONS

The soil varies greatly within this belt, depending largely upon the material from which it has been developed. In certain portions it is sandy, but throughout the area as a whole it may be said to consist of red loams and sandy loams. The rainfall penetrates to considerable depth, although it does not develop a decided profile, the soil appearing relatively uniform from the surface down to a depth of several feet. The root development of this forest is relatively near the surface, usually one to three feet. In many cases the roots have an unusually extensive surface development, extending many feet from the trunk and lying within a foot or two of the surface.

NATURAL PRODUCTION

This type of country is not regarded at the present time as an especially good game country, owing probably to the ease with

which game can be exterminated where the hunter is well protected by vegetation. To a very great extent game has been killed out in the southern portion of the area, although a large number of wild animals were probably supported here originally, at least during the growing season. The drought period is severe, however, and during such periods there are often extensive areas where it is difficult to obtain drinking water. During these drought periods forage can be secured only along the rivers or where there is more than a normal moisture supply in the soil.

In certain sections primitive man has found an abundance of wild fruits, while civilized man has been able to secure here timber of unusual value because of its resistance to termites, and native rubber, which in portions of the country is quite abundant.

AGRICULTURE

Primitive agriculture is well developed in these areas. Sorghum is the most important crop, but others also important are maize, pennisetum, cucurbits, sweet potatoes, beans, gourds, tobacco, hemp. In the warmer portions manioc, rice, and sugar cane are grown.

Agricultural practice varies somewhat in the different tribes, and no detailed description will hold throughout. As a rule the soil is prepared for planting by the men, that is the timber and grasses are cleared away. The women then grow the crop, care for it and harvest it, and prepare the product for consumption. Mixed culture is the rule.

At Elizabethville raised beds were planted to maize, sweet potatoes, and peanuts. Often eleusine and sorghum are grown in relatively pure stands. In much of this country the ant hills are prized for crop production. The trees are cut, leaving high stumps, the brush is burned, and maize, sorghum, pumpkins, sweet potatoes, tomatoes, etc., are planted. Often in the less densely inhabited portions seeds are put in where a log or stump has burned or been eaten by termites, and the crop is allowed

to mature without other attention. This method was employed with maize, tomatoes, and cucurbits in Northern Rhodesia.

A relatively small amount of this country has been put under crop by Europeans. Tobacco, cotton, maize, sorghum, and potatoes have been grown to some extent, especially in portions of Northern Rhodesia. One of the chief difficulties in growing grain or root crops in isolated fields is the abundance of baboons, which often entirely destroy the crop. The best results can be obtained only by irrigation, since the drought period is relatively long.

(Baum, Burton, Burtt-Davy 1905–06, Busse 1901, Cameron, Dickens, Farini, Hock, Leplae 1921, Livingstone 1858, 1865, 1874a, J. A. Moloney, Neave 1906–07, Salt, Serpa Pinto, Speke, Stevenson-Hamilton, Stuhlmann 1895a, Thomson, Thornhill, Vasse 1909, L. A. Wallace)

CROP POTENTIALITIES

Land characterized by this type of vegetation is capable of producing good crops of maize, sorghum, millet, pennisetum, cotton, sweet potatoes, sesame, tobacco, beans, indigo, groundnuts, and rubber; and near the equator it will produce manioc, rice, and bananas.

Thorn Forest

Fig. 12; *T* on map

A dense growth of thorn trees, usually from 10 to 20 feet in height, is the dominant feature of this vegetation type. During the growing season these trees are a mass of foliage and flowers. The growth period is short, however, and during the greater part of the year the trees are leafless, but often the thorns stand out prominently. Such thickets are difficult to pass.

BOTANICAL DESCRIPTION

The species vary considerably in different portions of this area. As a rule acacias are dominant. The following plants

are characteristic. In South Africa (Evans 1920–21, Passarge 1904, Seiner 1909, 1910, 1912, 1913):

Acacia horrida Willd.
Acacia dentinens Burch.
Zizyphus mucronata Willd.
Acacia hebeclada DC.
Tarchonanthus camphoratus L.
Boscia pechuelii Kuntze
Combretum apiculatum Sond.
Acacia heteracantha Burch.
Dichrostachys nutans Benth.
Acacia spirocarpoides Engl.

In East Africa (Busse 1900–01, 1908a):

Acacia spirocarpoides Engl.
Balanites aegyptiaca (L.) Delile
Acacia Senegal Willd.
Sansevieria longiflora Sims

In North Africa (Chudeau, p. 399; Duveyrier 1864, p. 615; Paoli, p. 152; Schweinfurth 1868, p. 125):

Acacia tortilis Hayne
Acacia verek Guill. & Perr.
Acacia arabica Willd.
Acacia spirocarpoides Engl.

Throughout almost the whole area Euphorbia is a prominent feature.

A very luxuriant phase of this forest is shown in such areas as the Addo bush, which is made up of a much larger variety of species than some of the drier thorn forest. Among the more important plants in this bush are:

Portulacaria afra Jacq.
Schotia speciosa Jacq.
Acacia horrida Willd.
Asparagus sp.

Carissa arduina Lam.
Crassula perfoliata L.
Ehretia hottentotica Burch.

and many other thorny plants. *Sansevieria thyrsiflora* Thunb. is one of the common plants of the undergrowth. (For a more complete list see Schoenland 1919).

DISTRIBUTION

Where, in the acacia-tall grass savana, the trees thicken up to shut out the grasses, dry forest is formed. In the same manner in the acacia-desert grass savana a thickening of the trees forms the thorn forest. This type, therefore, occurs in scattered small areas throughout the whole of the acacia-desert grass savana in all the drier portions of Africa. In its most luxuriant phases it is found in the Addo bush in South Africa and in the Saxenwald inland from Dar-es-Salaam in Tanganyika Territory. Where the desert conditions prevail the vegetation consists of small thorny bushes, which in many cases form almost impenetrable areas. The thorn forest is distributed from the Atlantic Ocean across the southern part of the Sahara to the Abyssinian highlands, around these highlands to the north and east, and down across Somaliland to the center of Tanganyika Territory. It is then interrupted and occurs again in the southwest, in the Kalahari, Southwest Africa, and certain sections of the eastern Karroo. Often in the acacia-tall grass savana it is not uncommon to find thickets of thorn trees, especially where the soil is heavier and impervious. Such areas cannot well be indicated on the map, primarily because of lack of data as to their location.

CLIMATIC CONDITIONS

The climatic conditions are essentially the same as those discussed under the acacia-desert grass savana (p. 65).

SOIL CONDITIONS

The soil conditions are similar to those discussed under the acacia-desert grass savana (p. 65).

FIG. 12.—Thorn forest. An acacia thicket during the drought rest period. Guaso Nyiro, Kenya Colony, June 15, 1926.

FIG. 13.—Temperate brush. A general view. Shows Ericas, Metalasia, and Polygolas at the beginning of the flowering season. Table Mountain, Cape Province, Aug. 23, 1919.

NATURAL PRODUCTION

The principal natural product of this type of forest is browse for certain wild animals, notably giraffe, rhinoceros, and in some instances elephants. This type has been unproductive for primitive man.

The principal exports consist of gums gathered from the thorn trees in the northern portions of the area. Land of this type is, with the exception of the very best portions, entirely unsuited to agriculture.

Temperate Brush

(Cape Vegetation, Maqui)

Fig. 13; *B* on map

Temperate brush is characterized by a relatively luxuriant growth of bushes and small trees. The bushes range in size from minute ericas to treelike proteas. In the Cape region a wealth of ornamental bulbous plants, including many species of lily, iris, amaryllis, and also arum lilies and pelargoniums characterize this formation and comprise by far the richest display of interesting flowering plants to be found in any portion of Africa. In the maqui of North Africa the display of ornamentals is by no means as prominent. It is composed of evergreen bushes, among which ericas are prominent. The regions closely resemble each other otherwise and are generally considered the same vegetation type.

Temperate brush resembles closely the chaparral of California in general character of growth and in the climatic conditions indicated.

BOTANICAL DESCRIPTION

This area is the best known botanically of all portions of Africa and has been fully described. A long list of notable contributions has been made, based on collections in the Cape region. Probably the most detailed local descriptions are by Bolus and Marloth. Only a few of the species which characterize this type can be mentioned. One of the most dominant

species is *Elytropappus rhinocerotis* (L.) Less. Other species characteristic of large areas are *Eriocephalus umbellulatus* Cass., *Euryops tenuissimus* Less., and *Metalasia muricata* R. Br. On the mountain slopes there are *Leucadendron argenteum* (L.) R.Br., *Protea mellifera* Thunb., *Protea lepidocarpodendron* L., *Protea neriifolia* R.Br., *Olea verrucosa* Link, *Rhus tomentosa* L., *Myrsine africana* L., *Protea grandiflora* Thunb., *Leucospermum conocarpum* R.Br., *Leucadendron plumosum* R.Br., and *Mimetes lyrigera* Knight.

The flora is characterized largely by the Proteaceae and Ericaceae, although the Liliaceae, Iridaceae, Amaryllidaceae, Orchidaceae, Restionaceae are exceptionally abundant in species. Pelargonium is also well represented.

The Cape region contains one of the richest floras found in any section of the world.

Closely allied to the Cape vegetation is the maqui of the Mediterranean, as represented in North Africa. It consists of evergreen shrubs such as *Myrtus communis* L., *Olea europaea* L., *Quercus ilex* L., *Ilex aquifolium* L., *Erica arborea* L., *Erica corsica* DC., and *Prunus spinosa* L. Bulbous plants are by no means as numerous as in the Cape region. Crocus and hyacinths occur, and smilax, roses, and clematis aid in developing a dense thicket which is not easily penetrated.

(Bews 1916, Bolus 1893, 1905, Bunbury, Burchell, Cosson, Diels, Elliot, Engler 1910, Gindre, Marloth 1905, 1908, H. H. W. Pearson 1911, Pitard and Proust, Trabut 1888, 1892, Vahl, Weiss 1905)

DISTRIBUTION

The temperate brush land of South Africa is limited to a small portion, generally known as the Cape region. It occupies only the mountain ranges in the southern extremity of Africa and the slopes on the southern side of these mountains extending to the ocean. It is interrupted at certain points in the high elevations by temperate forests and gives way inland to the Karroo or desert shrub. This type occupies a similar region in North

FIG. 14.—Temperate brush. A vineyard of Kanipoot grapes; peaches in background. Oak and pine are shown on the mountain. Agriculture has been developed to a high degree in this type. Wynberg, Cape Province, Aug. 18, 1920.

Africa, occurring in Morocco, Algeria, Tunis, northern Libia, and in Madeira and the Canary Islands. Here it occupies the lower rolling or hilly land between the Mediterranean grassland valleys and the oak-conifer forests of the higher mountain ranges.

CLIMATIC CONDITIONS

Rainfall varies from 20 to 35 inches. There is a long drought period from three to five months in midsummer in the Mediterranean regions. In the Cape region the rainfall is largely during the winter months, although the distribution is not sufficiently unequal to cause the drought period, which is from three to four months in length, to be felt with special severity by the vegetation.

SOIL CONDITIONS

The soils are brown, with reddish subsoils, and, although usually deficient in lime, are still productive of good cereal and fruit crops.

NATURAL PRODUCTION AND AGRICULTURE

Before the advent of the white man wild animals were relatively abundant in the Cape region. Although grazing conditions are not of the best, this country still affords grazing for considerable numbers of domestic animals, such as horses, cattle, sheep, goats, and ostriches. Primitive man found here little on which to subsist, except forage for his cattle and the wild game. Under European methods this region has become most productive of temperate fruits and cereals. Grapes probably occupy the principal place in fruit production in the Cape region (Fig. 14), where the greater majority of them are made into wine. Temperate fruits such as apricots, pears, peaches, and apples; citrus fruits —tangerines, oranges, and lemons; and temperate vegetables and cereals—wheat, oats, and barley—are the principal crops. Large quantities of table grapes are exported to Europe, and a relatively small number are sold as raisins. The principal tem-

perate fruit crops exported fresh are apples, pears, grapes, oranges, peaches, plums, and tangerines.

(Bernard and Ficheur, Nobbs R. Wallace)

CROP POTENTIALITIES

The principal products of this type of land are the temperate cereals, also maize, sorghum, tobacco, alfalfa, and temperate and subtropical fruits, especially olives, grapes, citrus, apples, pears, apricots, and plums.

Oases

Fig. 15; *O* on map

Within the desert areas, wherever a supply of fresh water reaches the surface, there is produced a subirrigated or surface-irrigated area known as an oasis. These spots have been sought out by man and converted into productive orchards and gardens. It is therefore unlikely that any very desirable areas which have not thus been modified could be found. Since water is the chief limiting factor in plant growth, any plants which have foliage well enough protected to withstand the heat of the sun and the force of driving winds, often carrying sand, are able to succeed in this region. An oasis is usually marked by a thicket of trees such as date palms, acacias, or species of Ficus, Zizyphus, and Tamarix. It is difficult to separate the original vegetation from that which has been introduced. At the present time these oases appear as forests of date palms, the space underneath the trees often being devoted to the growth of vegetables and cereals.

BOTANICAL DESCRIPTION

Probably among the more important trees are the date palm (*Phoenix dactylifera* L.), the doum palm, *Hyphaene thebaica* (Del.) Mart., and, in addition, *Acacia arabica* Willd., *Ficus* spp., *Zizyphus spina-Christi* Willd., *Tamarix articulata* Vahl, *Tamarix gallica* L., *Salix safsaf* Forks., and *Acacia albida* Delile.

FIG. 15—An oasis. Dates in the foreground. Irrigated land at the right. Luxor, Egypt, Aug. 28, 1920.

DISTRIBUTION

Oases occur primarily throughout the Sahara. Any irrigated land within the arid and semi-arid region may be regarded as an oasis. The greatest area of land of this type is that of the Nile valley, where immense quantities of cotton, cereals, and dates are produced. These oases are scattered throughout the whole of the Sahara, and somewhat similar areas are developed in the southern desert region of the Karroo and Southwest Africa, where desert lands are by the aid of irrigation made productive of temperate and subtemperate fruits and field crops.

CLIMATIC CONDITIONS

Oases are developed in regions of very little rainfall, and crop production is not at all dependent upon the rainfall, which ranges from 2 to 20 inches. The air is for the greater part of the year excessively dry and the temperature high.

SOIL CONDITIONS

The soils are rich, desert alluvial lands, in some cases slightly impregnated with salts.

NATURAL PRODUCTION

Under natural conditions without the aid of man these areas would be productive of pasturage, gums, and fruits.

AGRICULTURE

These oases have been made into probably the most productive agricultural areas in the world. Here are grown chiefly dates, also figs, pomegranates, apricots, peaches, apples, oranges, citron, grapes, pistachio, olives, cotton, tobacco, castor bean, potatoes, beans, almonds, sorghums, okra, pennisetum, and all types of subtropical fruits and vegetables.

(Ball and Beadnell, Barth, Beadnell 1901, 1901a, Brunhes, Duveyrier 1864, Garstin, Mathuisieulx, Monteil, Schweinfurth 1869–71)

CHAPTER III

THE GRASSLANDS

In this chapter we shall take up the grasslands, the second of the three broad groups into which the vegetation types of Africa may be divided.

High Grass-Low Tree Savana

Fig. 16; *ss* on map

The high grass-low tree savana is composed of a coarse, rank growth of grasses from 5 to 12 feet high. The grasses do not form a turf, each plant usually being distinct at the base and somewhat resembling broadcast seeding of the coarser cereals. Growth is rapid, but during the drought period following maturity the grasses dry out and are burned to the ground (Busse 1908a). At the beginning of the rainy season the fresh young blades shoot up again, forming a dense fresh green cover. Scattered through this grassland are a large number of trees of which the lower branches are in, or barely above, the full-grown grass cover. At other times the clumps are somewhat larger, forming a park landscape.

Except where paths are made, it is difficult to walk through this grass region; and it is even more difficult to secure photographs which adequately represent the type. For a short time following the burning of the grass the whole country presents a blackened surface, with the trees standing out distinctly with scorched trunks and dead leaves. But this appearance is changed as soon as the grasses start growth and the trees again come into leaf. The paths then lead between walls of tall grass, which are difficult to penetrate.

During the dry season the region resembles a dry yellow grainfield.

FIG. 16—High grass-low tree savana. The grasses are about 8 feet high and reach well into the lower limbs of the small trees. Often the trees are much less prominent. North of Kongolo, Belgian Congo, Jan. 23, 1920.

FIG. 17—High grass-low tree savanna. Native agriculture. Banana, rice, manioc, and maize just coming up. Kongolo, Belgian Congo, Feb. 6, 1920.

BOTANICAL DESCRIPTION

This region is an immense prairie dominated by Andropogon and Pennisetum, with small trees scattered through. Prominent trees are *Bauhinia reticulata* DC., *Acacia suma* Kurz, *Parkia africana* R.Br., *Butyrospermum parkii* Kotschy, *Lophira alata* Banks, *Cussonia djalonensis* Cheval., *Entada sudanica* Schweinf., and species of Annona, Kigelia, Erythrina, Strychnos, Borassus, Hyphaene, Gardenia, and many other genera. Among the grasses should be mentioned *Pennisetum benthami* Steud. and *Imperata cylindrica* (L.) Beauv.; also *Pennisetum purpureum* Schum., *Hyparrhenia rufa* (Nees) Stapf (*Andropogon rufus* Kunth), *Andropogon lepidus* Nees, and *Andropogon schimperi* Hochst.

Grasses characteristic of this area in the upper Congo region are *Manisuris exaltata* (L.) Kuntze, *Imperata cylindrica var. Thunbergii* Dur. & Schintz, *Hyparrhenia rufa* (Nees) Stapf, *Andropogon tenuiberbis* Hack., *Jardinia congoensis* Franch., and *Pennisetum setosum* Rich.

(Busse 1905, 1920, Chevalier 1907, 1909, 1910, 1920, Engler 1908, Hassert 1917, Jentsch and Büsgen, Rendle 1913, Thompson 1910a)

DISTRIBUTION

The high grass-low tree savana forms an almost continuous border around the tropical rain forest. Starting in Senegambia in the west it extends eastward in a broad band interrupted only by the highlands of Cameroon and extends beyond the Nile, where it turns south to occupy most of Uganda. The highland of eastern equatorial Africa is not traversed by this type, but it occurs in the Congo south of the forest and extends in a broad belt across into Portuguese West Africa and French Equatorial Africa. The area occupied by this type is greater than that covered by the tropical rain forest but not as great as the acacia-tall grass savana, which forms a band on the drier sides of the high grass-low tree savana (see Table I, p. 19).

(Du Bourg, Dufour, Güssfeldt *et al.*, H. H. John-

ston 1902, F. D. Lugard, Meyer 1909–10, Pogge 1881–82, Ritter, Sanderval, Thompson 1910a, Whitlock)

CLIMATIC CONDITIONS

This area lies in a region of heavy rainfall, 35–60 inches, or even more in Liberia and the Middle Congo district of French Equatorial Africa, where the rainfall is sometimes as high as 75 inches. The dry season north of the equator is from November to February. In December to February the *harmattan* from the north and northeast carries clouds of dust from the Sahara down over the northern area of this type. In the south the dry season falls from May to August.

SOIL CONDITIONS

For the most part on the level uplands the soil under this type is lateritic loams and laterite. Where the land surface is not flat it is much less leached and consists of red loams, which are more productive. There is also a relatively large amount of alluvial land in this area, and it is often marked by an exceptionally good growth of elephant grass (*Pennisetum benthami*).

NATURAL PRODUCTION

The amount of forage produced in this type is unusually large, but for the greater part it is coarse and not of the best quality for the smaller herbivora. The elephant, buffalo, rhinoceros, water buck, impala, reedbuck, and many other animals find here a favorable habitat. It is, however, not characterized by the immense herds of wild game which occur in the drier sections. Primitive man has found here a number of most useful plants, chief among which, as in the tropical rain forest (pp. 28–29 and Fig. 35) should be mentioned the oil palm, which furnishes food, oil with which to smear his body or to make soap, and also wine. The shea tree grows along the drier edge of this type south of the Sahara and is one of the important oil-producing plants of Africa. Civilized man has found the oil of this tree (shea butter) and of the oil palm, together with rubber plants

FIG. 18—High grass-low tree savana. Coffee plantations, with a windbreak of Grevillea in background. Typical of young plantations in Uganda. West of Misindi, Uganda, July 19, 1920.

FIG. 10—High grass-low tree savana. A plantation of manioc (*Manihot esculenta*) about four years old. Plants 10 feet high and ready to be dug out to give place to a new crop. Konzolo, Belgian Congo, Feb. 6, 1926.

and the ivory from elephant herds, the most useful articles of export from this type of country.

AGRICULTURE

Throughout this whole section agriculture is practiced by the native tribes. In fact, the area is not as well suited to pastoral life as the acacia-tall grass savana, and the natives are therefore compelled to resort to agriculture to produce a sufficient food supply. Only a small portion of this land is cultivated.

The natives are very careful in the selection of land for crop production, choosing only those areas which possess the best soil. The dry period, which is much shorter than in the acacia-tall grass savana but relatively more severe than in the tropical rain forest, limits crop production somewhat. There is, however, a very wide range of food plants and other plants produced in this section.

Travelers in the high grass-low tree savana of the southern Belgian Congo have found almost the same range of cultivated crops that they have in the north. The range of crops grown by the natives is very wide. Not only do they grow the principal warm-weather cereals, such as sorghum, eleusine, pennisetum, rice, and maize, but such root crops as manioc, sweet potatoes, yams, colocasia, and a wide range of vegetables, including pumpkins, squashes, gourds and cucumbers, beans, tomatoes, sesame, peanuts, voandzeia, oil palm, indigo, bananas, cotton, tobacco, sugar cane, oranges, lemons, annona, pineapples, pigeon peas, cowpeas, onions, etc.

Mixed cultures are the rule, and it is seldom that a stand of any one crop is found in a native garden (Fig. 17). In the Belgian Congo and in Uganda the beds are often raised a foot or two above the level of the ground and are planted to several crops at the same time, such as maize, peanuts, and sweet potatoes, or to maize and manioc. Manioc is a perennial crop, and after about four years it forms a dense pure stand and is dug out to give place to a new crop (Fig. 19). In almost all cases the

plantings are made at various times, and one will find all stages between ripe maize and seedling maize in the same plantation.

Throughout this whole area, except on the drier edge, cattle are not an important element, and the stock consists chiefly of goats, sheep, pigs, and chickens.

(Alexander, Bauer, Brown and Hunter, Busse 1905, 1920, Capello and Ivens, Chevalier 1909a, 1912, 1916, Dudgeon, Du Plessis, Dybowski, Frobenius, Haywood, Hilton-Simpson, Hupfeld, H. H. Johnston 1902, 1908, Julien, Kumm, Lenfant, Leplae 1914, Livingstone 1858, Machat, Maistre 1893a, Meyer 1909–10, Moseley, Newland, Nugent, Ollone 1901, Pogge 1880, 1881–82, Raphael, Ravenstein, Salesse, Sanderval, Sarolea, Seefried, Sprigade, Torday, Vandeleur, Wissmann 1889, 1891, Wolff, K. Zimmermann *et al.*)

Although this land is usually not as productive as forest land, there are in this area many tracts which are capable of producing excellent crops when managed by European farmers. The principal crops attempted are grain crops of all kinds, chiefly maize, sorghum, rice, and more especially such crops as cotton, coffee, sisal, Ceará and Pará rubber, and manioc.

Only a relatively small portion of this area has as yet been brought under cultivation by white men. In Uganda there are large coffee plantations (Fig. 18), also large plantings of cotton. In Sierra Leone and certain portions of the Belgian Congo and the Congo districts of French Equatorial Africa there are areas brought under European agriculture.

CROP POTENTIALITIES

The potentialities of land of this type are very great, and a mere list of plants which can be grown would be unusually long. A few of the more important are rice, manioc, yams, ginger, maize, rubber, sugar cane, colocasia, sorghum, sweet potatoes, potatoes, cotton, tobacco, beans, indigo, peanuts, voandzeia, pen-

nisetum, eleusine, sesame, bananas, annona, pineapples, guava, citrus of all kinds, coffee, cucurbits, oil palm, and, in certain portions, vanilla, cacao, and tropical fruits and vegetables.

Acacia-Tall Grass Savana

(Low Veld, Tree Steppe, Orchard Steppe, Park Land)

Figs. 20 and 21; *s* on map

An even distribution of tall (3–5 feet) grass forming an almost continuous grassland through which are scattered trees, from 10 to 50 feet in height, characterizes this formation. The trees are often thorny and flat-topped, but this is by no means characteristic of the whole area. They may be uniform in size or may vary from very small to relatively large trees. During the long drought period the grasses are usually reddish or pale yellow and when fully dry are often burned, leaving the interspaces between the trees blackened and barren. During this period the trees are leafless. Usually the trees and large-rooted perennials begin growth just before the rainy season. Many flowers are developed, and a verdant foliage follows shortly after the first rains. Rainfall is often heavy, and the growth of the grasses especially is unusually luxuriant. With the trees in full leaf over a luxuriant grass cover, the appearance is that of a great orchard, or, if the trees are distributed more unevenly, the impression is that of a park.

BOTANICAL DESCRIPTION

The composition of this vegetation type varies in different portions of the continent. When the magnitude of the area occupied by this type is considered, it is remarkably uniform. Species of Acacia and Combretum are especially abundant and are among the more important components of the woody vegetation; with these are associated other species. The following are among the more important woody species:

Acacia giraffae Willd.
Acacia albida Delile

Acacia arabica kraussiana Benth.
Terminalia sericea Burch.
Sclerocarya caffra Sond.
Burkea africana R. Br.
Dichrostachys nutans Benth.
Combretum zeyheri Sond.
Combretum apiculatum Sond.
Acacia seyal Delile
Acacia arabica Willd.
Zizyphus spina-Christi Willd.
Acacia spirocarpoides Engl.

The important grasses are:

Themeda triandra Forsk.
Andropogon hirtiflorus Kunth
Heteropogon hirtus Pers.
Hyparrhenia hirta (L.) Stapf
Hyparrhenia ruprechtii Fourn.
Andropogon ruprechtii Hack.

The baobab, *Adansonia digitata* L., although not limited to this area, is often a prominent tree in North, Central, and South Africa.

(Aitken, Aitken and Gale, Bews 1909–13, 1916, 1917, 1917a, 1918, Browne, Burtt-Davy 1905–06, 1905–06a, Chevalier 1907, Dove 1903, Eckersley, Engler 1906, 1908, 1910, Evans 1918, 1920–21, Heering and Grimme, Jaeger 1911–13, Junker 1877, E. J. Lugard, Marloth 1905, Meyer 1913, Mildbraed 1914, Muriel, Pegler, Rendle 1911, Schweinfurth 1868, Seiner 1913, T. R. Sim 1909, Swynnerton, Thode 1890, 1894, Thompson 1920, Vageler)

DISTRIBUTION

The acacia-tall grass savana is the most extensive formation in Africa (Table I, p. 19). It extends across the continent eastward

FIG. 29—Acacia-tall grass savana. A general view. Shows grassland with scattered trees (*Zizyphus spina-christi*). Between Nimule and Rejaf, Anglo-Egyptian Sudan, July 29, 1920.

FIG 21.—Acacia-tall grass savana. General view of grass-land (*Themeda triandra*) and flat-topped acacias. Between Archer's Post and Meru, Kenya Colony, May 27, 1920.

FIG. 22—Acacia-tall grass savana. A native field of sorghum, one of the most important crops, Kisumu, Kenya Colony, July 11, 1920.

from Senegambia south of the Sahara, broadens out to surround the Abyssinian and Somali highlands, extends south across portions of Kenya Colony and Tanganyika Territory and on down the eastern coast to the southern part of Natal. It also turns west and northwest across the northern Kalahari to Portuguese West Africa.

COMPARISON WITH ADJACENT COMMUNITIES

This formation is distinguished from the acacia-desert grass savana chiefly by the character of the grasses. They are taller and more luxuriant and have a much longer growing season. The trees are more varied, with fewer of the small desert thorn trees, such as *Acacia horrida* and *Zizyphus mucronata*, and more of taller, less thorny types, such as *Burkea africana* and Combretum.

It is distinguished from the dry forest only by the grassland areas. In the dry forest the trees predominate, while in the acacia-tall grass savana the trees are often far apart. In other words, when trees grow close together, preventing a luxuriant grass growth, this type passes over to the dry forest.

It is distinguished from the high grass-low tree savana by the shorter and finer grasses. The trees are also much taller in proportion to the grasses, and their crowns are generally far above the tops of the grasses. The drought period is much longer, and there is a lighter rainfall. The grasses are not large or thick enough to interfere decidedly with travel, while in the high grass-low tree savana it is difficult to walk through the coarse grasses.

NATURAL PRODUCTION

The grazing in this formation is not especially good when the grasses are coarse and unpalatable; the vegetation is then known as "sour veld." Where Themeda and other palatable grasses predominate it constitutes excellent grazing land and is known in South Africa as "sweet veld." During the dry season the forage is not good, and wild game and cattle rely at such times largely on the grasses along the river courses. This type sup-

ported large herds of wild game and constituted good hunting country before the wild herds had been destroyed or driven out. Here antelope, eland, rhinoceros, springbok, hartebeest, wildebeest, elephant, giraffe, zebra, and lion were abundant, and are still found, especially in portions of East Africa. Huge troops of baboons find here fruits and roots on which to subsist. In every way this type is a productive one.

AGRICULTURE

Primitive man found here fruit trees and a supply of animal food which enabled him to live as a hunter. For the most part, however, he developed into a grain grower, since the grain sorghums here reach their greatest development and form a reserve food supply to carry the people over the severe drought periods. Grain is the staple food for the relatively large number of natives found in this area. In addition to the warm-season grains such as sorghums (Fig. 22), maize, eleusine, and pennisetum, such crops as beans, sweet potatoes (Fig. 23), and peanuts are important. This is the great sorghum and peanut-producing area of the continent.

In the lower country of East Africa manioc, sugar cane, and rice are grown. Besides the crops mentioned there are grown by the natives pumpkin, squash, and other cucurbits, cotton, tobacco, beans, cowpeas, sesame, indigo, castor beans, voandzeia, tamarinds, tomatoes, and fruits.

Primitive agriculture varies with the tribes. As a rule it is mixed culture. In the choice of land the natives use excellent judgment for the most part, being careful to select the best soil areas. Usually small-timbered patches and termite hills are selected as yielding the best crops. The land is worked up with hoes by the men. The trees, if too abundant, are cut off, leaving high stumps. In some places the fields are small or very often consist of a single kind of plant. When the native population is dense one finds almost continuous fields, often separated by rough brush fences or hedges. The crops are usually grown in

FIG. 23—Acacia-tall grass savana. A native planting of sweet potato. Hills are carefully made and kept free of weeds for some time. Between Nimule and Rejaf, Anglo-Egyptian Sudan, July 26, 1920.

FIG. 24—Acacia-tall grass savana. A seedling orange orchard nine years old, developed in the low veld. Rustenberg, Transvaal, Oct. 14, 1919.

mixed culture and are not all of the same age. Lower lands well supplied with water are utilized during the dry season.

Pasturage is afforded for stock such as goats, sheep, cattle, horses, and donkeys. It is in this type that the great pastoral tribes have developed; but diseases have made somewhat uncertain the utilization of this land for grazing, and portions of it cannot be developed without great difficulty.

Only in the southern part has land of this type been extensively brought under cultivation. Here it has proved productive of maize, sorghum, citrus fruits (Fig. 24), mango, avocado, pineapple, annona, and other subtropical fruits and vegetables. Cotton, sisal, Pará rubber, tobacco, and many other crops have been successfully grown in the more tropical portions. But for the area as a whole a very small portion is now under cultivation.

(Ancelle, Austin 1901, Barth, Bauer, Bayol, Bowdich, Burton, Burtt-Davy 1905–06b, Churchill, Dalziel, Du Bourg, Dudgeon, Dyé, Eckersley, Emin Pasha, Engler 1893, Farini, Fitzsimons, Freydenberg, Fuchs, Fülleborn, Gibbons 1904, 1906, 1907, Gleichen 1905, Goetze, Gregory 1894, 1896, Gruvel, Hamilton, Hayes, Hecquard, Henrique, Hobley, Hore, Hulot, Humphries, H. H. Johnston 1902, Junod, Koettlitz, Leverson, Livingstone 1858, 1865, Lloyd, L. McLeod, Maugham, Michel 1900, Orr, Paulitschke, A. N. Pearson, Peters, Pfeil, Plat, Pringle, Quintin, Raphael, Roosevelt and Heller, Schoenfeld, Schweinfurth 1871, T. R. Sim 1910, A. D. Smith 1900, C. S. Smith, Speke, Stevenson-Hamilton, Stuhlmann 1894, 1895, 1909, Swayne, Thiele and Wilson, Vasse 1907, Wellby 1900, Weule, Wickenburg, Wilkinson, Wise, Wollaston)

CROP POTENTIALITIES

Maize, sorghum, pennisetum, eleusine, sweet potatoes, sesame, tobacco, flax, sisal, peanuts, rubber, manioc, beans, cowpeas,

and indigo can be produced. In the tropical portions tropical fruits such as citrus, avocado, guava, pineapple, jack fruit, annona, banana; and, in the cooler portions, wattle, eucalyptus, pine, wheat, oats, barley, rye, potatoes, and coffee are possibilities.

Tall Grass

(High Veld)

Figs. 25 and 26; *g* on map

The tall grass formation is a pure grassland. The grasses are usually about three feet high and form a relatively continuous cover. The only objects which break the monotony are the termite hills, which are scattered throughout. They are often dome-shaped, two or three feet high, and of the color of the soil, which often matches that of the reddish grasses almost perfectly.

During the early part of the growing season, especially where fire has passed over and destroyed the old grass cover, there is a rich growth of perennials. These are followed after the first rains by a luxuriant grass growth. When the grasses approach maturity they present a reddish appearance. At this time this grassland looks at a distance much like the *Andropogon scoparius* areas in the prairie or plains region of the United States. The houses are very far apart and are usually surrounded by a few shade or fruit trees (Fig. 26). The roads often lead off directly from one point to another and do not follow property lines, and the wheel tracks are lowered below the surrounding surface. These conditions combine to make the resemblance very striking between the High Veld and the drier portion of our prairies. In the Transvaal and Orange Free State the grassland is interrupted only here and there by hills or small mountains which support tree vegetation. There are also trees along the banks of the rivers.

BOTANICAL DESCRIPTION

While there is a relatively rich flora of grasses and non-grass plants, by far the most important plant is the Rooi grass, *The-*

FIG. 15.—Tall grass. Typical high veld. An almost pure stand of Themeda. Pretoria, Transvaal, Oct. 11, 1919.

FIG. 26—Tall grass. Typical view. Farmhouse in the back. Ranches are very large and are devoted mainly to stock and corn. Vereeniging, Transvaal, Oct. 16, 1919.

meda triandra Forsk. This is the dominant grass of the High Veld. With Themeda are associated many other grasses of lesser importance, such as:

Hyparrhenia hirta (L.) Stapf
Heteropogon hirtus Pers.
Cymbopogon afronardus Stapf
Monocymbium ceresiaeforme (Nees) Stapf
Andropogon hirtiflorus Kunth
Tristachya rehmanni Hack.
Eragrostis brizoides Nees
Eragrostis gummiflua Nees
Andropogon schirensis Hochst.
Andropogon amplectens Nees

The principal perennials which spring into prominence after burning and even before the spring (September) rains begin and which have as a rule relatively large storage roots, are:

Elephantorrhiza burchellii Benth.
Hypoxis costata Baker
Aster serrulatus Harv.
Clerodendron triphyllum H. H. W. Pearson
Indigofera hedyantha Eckl. & Zeyh.

After breaking, the stages of succession are much as on our High Plains: first, a weed stage (dominated by *Tagetes minuta* L., with a lesser amount of *Erigeron canadensis* L.); second, a short-lived perennial stage (*Gnaphalium*); third, a short-lived grass stage (*Cynodon incompletus* Nees); fourth, a long-lived grass stage (*Eragrostis curvula* Nees, and other grasses); and a final stage of *Themeda triandra* Forsk.

(Bews 1909–13, 1916, 1917, 1918, Burtt-Davy 1905–06, 1905–06b, Eckersley, Evans 1918, 1920–21, L. McLeod, Marloth 1908, Phillips 1917, 1920, Schenck, Thode 1894, Trevor, Weiss 1905)

DISTRIBUTION

Although tall grass is shown on the map only for the southern Transvaal and the Orange Free State, it undoubtedly would have a much wider distribution if a detailed map of the vegetation of the whole continent could be shown. In many of the higher portions of the Low Veld (acacia-tall grass savana) this pure grassland occurs. In the Athi Plains near Nairobi, Kenya Colony, in portions of the East African Rift Valley and the highlands west of it, and in East Africa great areas of pure (Themeda) grassland occur.

CLIMATIC CONDITIONS

The climate is temperate, with frosts in winter. A rainfall of 35–40 inches comes chiefly during summer, with a drought period of four to six months in midwinter.

SOIL CONDITIONS

The soil is deep, dark brown to red, and shows little change in color at different depths.

NATURAL PRODUCTION

This great grassland originally supported enormous herds of wild game. Here herds of springbok, blesbok, steinbok, wildebeest, hartebeest, zebra, and roan antelope once found their favorite grazing grounds. The larger animals were also abundant, such as the white rhinoceros and the elephant (Fitzsimons).

The area affords excellent, although not strictly year-round, grazing and can support under natural conditions large herds of cattle, sheep, and other herbivora.

Native tribes here found not only excellent hunting grounds but ranges for their cattle, sheep, and goats.

AGRICULTURE

The region was originally inhabited by Kaffirs who reared flocks and grew crops of Kaffir corn, maize, beans, and vege-

tables. The Kaffirs are now largely replaced by white farmers who direct native laborers. Maize, known locally as "mealies," is the great crop of the Transvaal. Next in importance comes sorghum. But there are also produced quantities of potatoes, teff, sainfoin, and (under irrigation) alfalfa, tobacco, citrus, peaches, apples, pears, cherries, and barley and oats in winter.

Cattle, horses, sheep, and hogs are the chief domestic animals.

Acacia-Desert Grass Savana

(Orchard Steppe, Thorn Bush Steppe)

Figs. 27 and 28; *a* on map

The grass floor of this type may vary from a relatively even, short grass cover to a sparse, scattered growth of desert grasses. Over this grass cover are scattered small thorny trees or bushes. During the growth period the fresh green grass growth and the scattered small trees or bushes often resemble a young orchard. The evidence of drought is always present, the growth period is short, and during most of the year the trees are leafless and the grasses dry and light yellow in color. Even in this condition the type is excellent grazing land of low carrying capacity. The grass is so sparse that fire is not an important factor. After a long dry period and after rather heavy grazing the soil is left almost entirely bare, and the soil color enters into the general tone of the landscape. This overgrazing has a tendency to kill out the grasses, leaving only the trees. In the northern areas of this type, in the Sudan, this is especially true near the villages, where goats and sheep are kept. In many places in South Africa Rhizogum enters after overgrazing, just as Gutierrezia enters in the short-grass and desert-grass areas in the United States. There is a close similarity between the mesquite-desert grass areas of Texas and the acacia-desert grass areas of Africa.

BOTANICAL DESCRIPTION

The chief trees listed for South Africa are:

Acacia horrida Willd.

Acacia dentinens Burch.
Acacia heteracantha Burch.
Acacia hebeclada DC.
Acacia giraffae Willd.
Terminalia sericea Burch.
Tarchonanthus camphoratus L.
Zizyphus mucronata Willd.

A few of the more important grasses are:

Aristida uniplumis Lichtst.
Schmidtia bulbosa Stapf
Panicum nigropedatum Munro
Aristida hordeacea Kunth
Aristida stipiformis Lam.
Aristida rangei Pilg.
Aristida congesta Roem. & Schult.
Aristida burkei Stapf

(Almonte, Ancelle, Barth, Bews 1916, 1918, Blaizot, Bluzet, Bolus 1905, Büchner, Burchell, Chevalier 1907, Chudeau, Dove 1903, Dundas, Duveyrier 1864, Evans 1918, 1920–21, Fabert, Foureau 1901, Frey 1916, Freydenberg, Garde, Gautier, Gruvel, Gruvel and Chudeau, Höhnel, Hulot, Jessen, H. H. Johnston 1902, Labonne, Lefebvre, Lloyd, E. J. Lugard, Marloth 1887, Montandon, Nachtigal, Nieger, Nurse, Panet, Paoli, H. H. W. Pearson 1907, Peel, Pfeil, L. Schultze 1907, Schweinfurth 1869–71, Seiner 1910, 1912, 1913, A. D. Smith 1896, Tilho 1906, 1910, 1910–14, 1916–17, 1920)

DISTRIBUTION

The acacia-desert grass savana forms a relatively narrow strip between the acacia-tall grass savana on the humid side and the desert shrub-desert grass on the arid side. It does, however, cover an immense area in Africa. Starting north of the mouth of the Senegal on the west, it extends along the southern side of the

FIG. 27.—Acacia-desert grass savana. A general view. Shows scattered acacias, desert grasses, and Karroo bush. Kimberley, Cape Province, Sept. 25, 1919.

FIG. 28—Acacia-desert grass savana. Typical of much of this type. Scattered acacias on an open, desert-grass floor. The trees are almost leafless at this time. Merili, Kenya Colony, June 12, 1920.

Sahara in a band varying in width from 50 to 300 miles, across both the White and Blue Nile, and almost to the Red Sea. On the eastern side of Abyssinia it forms a relatively narrow belt, broadens out to form a wide belt in southeastern Abyssinia and Italian Somaliland, and extends south into Tanganyika Territory. It also extends south along the Rift Valley from Lake Rudolf. In South Africa, beginning near Kimberley, it forms a broad band across the southern Kalahari and extends northwest, reaching the Atlantic shore in the central coast region of Portuguese West Africa. In the Sahara, especially in the mountains, it often characterizes the drainage channels.

CLIMATIC CONDITIONS

Rainfall is light, ranging usually from 10 to 20 inches, with a drought period of five to eight months in winter. During the drought period the conditions are extremely arid, owing to high temperatures and absence of rain. The grass vegetation soon becomes dry in places, and the trees become leafless. The reserve of soil moisture is soon exhausted, and during the latter part of the drought period all vegetation is forced into a drought rest period.

SOIL CONDITIONS

Because of the small amount of precipitation, only the surface soil is moistened each year. There is therefore little leaching of the soil, and a lime hardpan is developed at about a foot or two beneath the surface. This marks the average penetration of soil moisture during each rainy season. Rapid growth of grasses and trees soon depletes the moisture, and the soil is dry to plant growth for long periods. The soils are gray or red sands or loams with a calcareous hardpan.

NATURAL PRODUCTION

The principal gum-producing districts in northern Africa are in this area, and gum constitutes one of the principal exports.

The acacia-desert grass savana is especially favorable graz-

ing land, and here are developed at times large numbers of herbivora, of which the following are important: eland, gazelle, zebra, oryx, ostrich, giraffe, elephant, rhinoceros, dik-dik, wildebeest, hartebeest, springbok, and the carnivora, such as the lion, chetah, jackal, hyena, and hunting dog.

Primitive man found here excellent hunting and also excellent range for his cattle. Much of this area is occupied by pastoral tribes such as the Hereros, Bechuanas, Gallas, and the Berbers and Fullas of the northern Sudan.

AGRICULTURE

Agriculture where practiced follows the rainy period and consists of such dry-land crops as sorghum, pennisetum, and peanuts. The sorghum is often planted on flood-land areas immediately after the subsidence of the water. This method is practiced about Khartum in the Sudan. This type marks the limit of production of dry-land crops.

The only use made by Europeans of land of this type is for pasturage for horses, cattle, sheep, goats, or ostrich. Agriculture is too precarious, suited only for extremely drought-resistant crops such as sorghum, peanuts, pennisetum, etc., and these are grown only during exceptionally wet years on areas which have had flood-water irrigation.

(Austin 1902, Aylmer, Drake-Brockman, Elliott, Gleichen 1898, 1905, Hodson, James, Roosevelt and Heller)

Desert Grass

Fig. 29; not shown on map

There are portions of the acacia-desert grass savana where trees give way entirely and the land is covered by a pure desert grass. Such areas are relatively extensive in South Africa and in East Africa. In northern Africa there are broad belts which constitute the well-known halfa areas, dominated by *Stipa tenacissima* L. This type of vegetation does not differ essentially from the acacia-desert grass savana or desert shrub-desert grass

FIG. 29—Desert grass. A pure open grass cover. Herd of native (Masai)cattle in background. Between Archer's Post and Meru, Kenya Colony, June 15, 1920.

FIG. 30—Mountain grassland. An even grass cover. Varied by proteaceous plants, gladioli, and sedges. Near N'gano N'gano, Urundi, March 16, 1920.

and has not been differentiated on the map. A large portion of the area shown on the map as desert shrub-desert grass in Morocco, Algeria, and Tunis should be included in the desert grass.

The principal natural products are forage for wild and domestic animals and, in the north, halfa, used extensively in paper making.

(Bernard and Ficheur; Manetti; Rikli, Schröter, and Tansley; Seiner 1913; Trabut 1889)

Mountain Grassland

Figs. 30 and 31; *m* on map

The mountain grassland is a pure grassland, the grass forming a relatively dense cover and growing from two to three feet high. Scattered through this grassland are large numbers of legumes and bulbous plants, which often add to the color of the landscape. Throughout practically the whole year this grassland is green, there being a relatively short drought period. The grass covers both the level areas, and the crests and sides of the mountains, occurring probably in many places where temperate forest previously existed. In every way it reminds one of a temperate rather than a tropical grassland.

BOTANICAL DESCRIPTION

In the highlands of Urundi the writer found this grassland made up largely of the following species (identifications by Agnes Chase, in the Bureau of Plant Industry of the U. S. Department of Agriculture):

Hyparrhenia filipendula (Hochst.) Stapf	One of the most important grasses of this highland and excellent for grazing.
Trichopteryx sp.	One of the most important grasses. Grows on the hills and is one to two feet high.

Sporobolus pyramidalis Beauv.	One of the more important grasses dominant on the lower slopes and grazed by cattle.
Ctenium concinnum Nees	One of the important grasses.
Eragrostis cilianensis (All.) Link	Relatively important, limited on the drier slopes.
Eragrostis chalcantha Trin.	Relatively important, limited on the drier slopes.
Microchloa indica (L.) Kuntze	Very abundant on hill tops but small and not a noticeable feature.
Themeda triandra Forsk.	Also a relatively important grass but not of primary importance.
Hyparrhenia rufa (Nees) Stapf	
Digitaria argyrotricha (Anderss.) Chiev.	
Aristida sp.	
Tricholaena rosea Nees	
Eragrostis sp.	A ruderal.
Eragrostis collocarpa Schum.	A semi-ruderal of some importance.

DISTRIBUTION

The mountain grassland occurs at high elevations in Central Africa, in the Abyssinian plateau, in the highlands of Kenya Colony and Tanganyika Territory; also on each side of the great Rift Valley, in the interlake region, and in the highlands about Lakes Tanganyika and Nyasa. Similar areas are found in the Katanga highlands of the Belgian Congo, in the elevated plateaus of the central Cameroons, and also in French Guinea.

(Bruce, Chevalier 1909a, Engler 1891, 1900, Jaeger 1911–13, Meyer 1913, A. Schultze, Shantz)

FIG. 31.—Mountain grassland. General view over mountains and valley. Shows pure grass cover. Bananas and grainfields at left. N'gano N'gano, Urundi, March 17, 1920.

FIG. 32—Mountain grassland. A native field of eleusine; grassland in the background. This is one of the chief crops grown by the Watusi. N'gano N'gano, Urundi, March 17, 1920.

CLIMATIC CONDITIONS

The climatic conditions are favorable for Europeans and for cattle. The temperature ranges from about 65° to 85° F. The rainfall is relatively heavy—40 to 60 inches. The drought periods are not severe, and year-round grazing is assured.

SOIL CONDITIONS

The soils are dark reddish loams or clays, free from hardpan, but rather thoroughly leached; and there is a tendency to form laterite where soils are left long in place.

NATURAL PRODUCTION

At the present time this grassland is so densely inhabited by natives that wild animals are almost excluded. Primitive man has here found the most valuable grazing land in the whole continent of Africa—a region in which the climatic conditions are favorable for cattle and where the grassland is of high carrying capacity. Goats and sheep are also kept by the natives, and in the Abyssinian highland horses as well. Stock raising is therefore of prime importance.

AGRICULTURE

Native agriculture is highly developed, even by such cattle-raising tribes as the Watusi of Urundi, among whom it is honorable for the men, including even the chiefs, to take part in planting the crop. The banana (Fig. 31) is probably the chief crop, followed closely by beans, of which many varieties are grown. Eleusine (Fig. 32), sorghum, and sweet potatoes are important. In many places irrigation is practiced. For Abyssinia many descriptions of the native agriculture can be found. The chief crops are:

Barley	Spice	Plums
Wheat	Tobacco	Oranges
Oats	Cotton	Lemons
Teff	Ginger	Peaches

Eleusine	Chickpea	Apricots
Maize	Lentils	Blackberries
Flax	Horsebean	Grapes
Sorghum	Castor bean	*Musa ensete*
Beans	Cucurbits	Sugar cane
Peas	Yams	Raspberries
Potatoes	Coffee	*Coleus tuberosa*
Pepper	Bananas	

Land of this type is admirably adapted to European agriculture. It is suitable for temperate cereals such as wheat, oats, barley, rye, and flax and is especially adapted to coffee. Citrus and temperate fruits such as apples, peaches, pears, plums, grapes, etc., do well when planted. No extensive areas have yet been developed, but rapid settlement has taken place in the highlands of Nyasaland and in Kenya Colony. For the most part these mountain grasslands are already densely inhabited, and the development of European plantations can only be accomplished by the displacement of the native inhabitants.

(Baumann, Blanc, Blundell, Borelli, Burgt 1903, 1906, Carpenter and Holm, Chevalier 1909a, 1909c, Combes and Tamisier, De Greef, Dimothéos, Dove 1890, Du Bourg, Ferret and Galinier, Frey 1914, Fuchs, Gorges, Gregory 1896, Gwynn, Harris, Hassert 1917, Heuglin 1857, Hotten, Humphries, C. Johnston, Kassner, Kenya Colony, Kerr-Cross, Koettlitz, Livingstone 1874, Maurette, Meyer 1909–10, Michel 1900, Neumann, Pringle, Rohlfs, Salt, Sclater, Stuhlmann 1894, 1909, Swayne, Trotha, Wellby 1901, Wickenburg, Wollaston)

CROP POTENTIALITIES

Temperate cereals such as wheat, barley, oats, rye, and flax, also warm weather cereals such as maize, sorghum, eleusine, and pennisetum do well. Here may also be produced beans, peas,

sweet potatoes, yams, colocasia, bananas, coffee, and other subtropical and temperate fruits and vegetables.

Alpine Meadow

u on map

The area above timber line consists of a low grass and herbaceous cover, of rock fields often lichen-covered, and of snow and ice fields. The meadow often forms a most interesting carpet of grasses and sedges and of especially interesting and attractive flowering plants.

DISTRIBUTION AND BOTANICAL DESCRIPTION

This type is limited largely to Mounts Kilimanjaro, Kenya, Elgon, and Ruwenzori. The economic importance of this type is negligible, but it is of absorbing botanical interest.

On Kilimanjaro (Volkens 1897) the lichens of the rock field which lies below the snow and ice fields are chiefly:

Parmelia latissima
Cladonia crispata
Floerkeana sp.
Amphiloma elegans
Candelaria vitellina
Parmelia adpressa
Buellia stellulata
Gyrophora umbilicarioides
Umbilicaria pustulata

Below this is a meadow composed largely of grasses, of which the following are among the most important:

Eragrostis olivacea
Koeleria cristata
Trisetaria quinqueseta
Setaria aurea
Andropogon exothecus
Festuca abyssinica
Deschampsia caespitosa

and the following grasslike plants:

Fimbristylis atrosanguinea
Cyperus kersteinii
Ficinia gracilis

Just above the forest, at the lower edge of the alpine meadow, there is a zone of vegetation two to three meters high consisting of:

Adenocarpus sp.
Ericinella mannii
Protea kilimandscharica
Helichrysum lentii
Euryops dacrydioides

At or near timber line a number of most interesting plants occur, among which are the arborescent Senecios, Lobelias, and Ericas—vegetable giants as compared with the other species of the same genera. Timber line is often formed by a zone of bamboo (usually *Arundinaria alpina* Schum.) 6 to 8 meters high.

(De Filippi, Meyer 1900)

Dwarf Palm-Temperate Grass

Fig. 33; *p* on map

This is a grassland often thickly overgrown with a dwarf palm or with shrubs.

BOTANICAL DESCRIPTION

The grasses are chiefly species of Bromus, Festuca, and Oryzopsis, with *Ampelodesma tenax* Link. The dwarf palm, *Chamaerops humilis* L., is common, as are numbers of herbaceous plants.

(Bernard and Ficheur; Duveyrier 1893; Flahault; Rikli, Schröter, and Tansley; Trabut and Marès)

DISTRIBUTION

This vegetation is limited to the valleys and the low hills and plains of the Atlas region and Cyrenaica in North Africa.

FIG. 33.—Dwarf palm-temperate grass. Principally dwarf palm (*Chamaerops humilis*), near Oran, Algeria. (From Rikli, Schroter, and Tansley, *Vegetationsbilder*, Ser. 10, No. 1–3, Section 2, Pl. 10.)

FIG. 34.—Marsh grass. In the foreground floating Pennisetum; back of this a zone of Echinochloa with a few maize plants put in by natives; beyond, a broad expanse of papyrus. Lualaba River, Belgian Congo, Jan. 18, 1920.

CLIMATIC CONDITIONS

The rainfall is low, 15 to 30 inches, with a drought period of two to six months in midsummer.

SOIL CONDITIONS

The dark brown to red soil is unleached and has a calcareous subsoil.

NATURAL PRODUCTION

The principal natural products are pasturage and palm fiber.

AGRICULTURE

Agriculture is primarily the production of cereals, wheat, barley, oats, rye, maize, sorghum, tobacco, alfalfa, and temperate and subtropical fruits and vegetables.

Marsh Grass

Fig. 34; *w* on map

Along river channels or lakes extensive areas of land which are not drained and whose soil is wet or covered with water much of the year develop a dense stand of hydrophytic grasses and grass-like plants.

The plants vary from 3 to 12 or 15 feet in height and present a rich green appearance. This is changed somewhat when grasses are in flower or when they die back. Often not a single tree breaks the expanse, but in many places the bright yellow flowers of small ambash trees relieve the monotony.

BOTANICAL DESCRIPTION

By far the most important plant is *Cyperus papyrus* L., which is dominant in most of the Central and East African swamps. Other plants of minor importance are:

Panicum pyramidale Lam.
Typha angustifolia L.
Phragmites communis Trin.

Panicum maximum Jacq.
Echinochloa pyramidalis (Lam.) Hitch. & Chase
Setaria aurea Hochst.
Sorghum arundinaceum (Willd.) Stapf
Vossia procera Wall. & Griff.
Cyperus latifolius Poir.
Scirpus corymbosus Heyne

Many swamp plants occur here, such as:

Polygonum senegalense Meissn.
Ipomoea aquatica Forsk.
Ipomoea palmata Forsk.
Luffa aegyptiaca Mill.
Vallisneria sp.

and lilies of various types. The only tree of importance is *Aeschynomene elaphroxylon* (Guill. & Perr.) Taub., the yellow flowers of which stand out above the papyrus swamp.

(Broun, Dyé, Engler 1894, 1902, 1910, Fries 1914, 1921, Hope, Meyer 1913, Mildbraed 1914, Tilho 1910)

DISTRIBUTION

In the highlands of Urundi and of Kenya Colony papyrus forms a dense thicket along many of the streams, and this is also true in Ruanda (Mildbraed 1914) and Urundi (Baumann) and other parts of Central Africa. The greatest papyrus swamps occur along the White Nile and the Lualaba, around Lakes Kisale, Bangweolo, Chad, Kioga, and in the Bahr-el-Ghazal.

(Fishbourne, H. H. Johnston 1908, Livingstone 1874a, L. A. Wallace, Willcocks)

CLIMATIC CONDITIONS

This type is not dependent directly on rainfall and is limited to frostless regions of the tropical portions of the continent.

NATURAL PRODUCTION

The fauna of this region is relatively rich. Here occur two species of otter, Mrs. Grey's water buck, hippopotamus, and

FIG. 35—Marsh grass. While not strictly growing in the marshes, the oil palm lines the low swamp banks of the Lualaba. Lualaba River, Belgian Congo, Jan. 17, 1920.

sitatunga. The elephant and buffalo often are found in these marshes.

The natives not only secure food from the wild animals but make extensive use of the ambash in the construction of rafts and huts. Papyrus is used extensively in thatching the huts, and the stems are used in the construction of the walls.

Along the banks of rivers, especially in the Congo drainage basin and the region lying between the Gambia and Congo Rivers, the oil palm finds a favorable habitat (Fig. 35).

Attempts have been made to manufacture paper from papyrus and to use the compressed plants for fuel for Nile steamers. These attempts have, however, not been successful.

AGRICULTURE

This land is of little or no value unless drained.

CHAPTER IV

THE DESERTS

In this chapter we shall discuss the deserts, the last of the three broad groups into which the vegetation types of Africa may be divided.

Desert Shrub-Desert Grass

Fig. 36; *Dg* on map

The desert shrub-desert grass type is distinguished from the desert shrub only by the occurrence of desert grasses between the desert shrubs. The grasses are usually small bunch grasses, which, although dry for the greater part of the year, are relatively good forage. Here are also included areas where the rains cause an ephemeral growth of grasses. This type is closely related on the one side to the desert grass and the acacia-desert grass savana and on the other to the desert shrub. The grasses seldom form a continuous turf and occur in isolated bunches.

BOTANICAL DESCRIPTION

In the north *Stipa tenacissima* L. is the most important grass, although there are many other important species, among which may be mentioned *Aristida pungens* Desf., *A. plumosa* L., *Panicum turgidum* Hochst. In South Africa the chief grasses are:

Aristida rangei Pilg.
Aristida obtusa Delile
Aristida capensis Thunb.
Aristida dregeana Trin. & Rupr.
Aristida subacaulis Steud.
Aristida brevifolia Steud.
Aristida adscensionis L.
Aristida vestita Thunb.

FIG. 46—Desert shrub-desert grass. Desert shrub with scattered tufts of Aristida. Good grazing and of low carrying capacity. Brakbosch, Cape Province, Sept. 17, 1919.

Aristida ciliata Desf.
Aristida namaquensis Trin. & Rupr.
Erasgrostis spinosa Trin.
Enneapogon scaber Lehm.

For shrubs see section on desert shrub, p. 78.

(Bernard and Ficheur; Bolus 1905; Burchell; Engler 1908; Evans 1918, 1920–21; Foureau 1905; Garde; Gruvel; Marloth 1908; Mathuisieulx; Monteil; Rikli, Schröter, and Tansley; Schweinfurth 1868)

DISTRIBUTION

This vegetation forms a belt between the acacia-desert grass savana and the desert shrub. It is really the more grassy part of the desert shrub and has usually a higher value as grazing land. It forms a narrow band between the tall grass and the desert shrub in the Orange Free State and extends north and west and also forms a belt extending north into Portuguese West Africa. In northern Africa it forms a narrow belt around the Sahara and around Abyssinia on the north and east and down the eastern coast of Somaliland into Kenya Colony.

CLIMATIC CONDITIONS

The rainfall is low—a little higher than in the desert-shrub areas and a little lower than in those of the acacia-desert grass savana—usually 5 to 15 inches.

SOIL CONDITIONS

The soils are gray or reddish desert sands and loams, calcareous and unleached.

NATURAL PRODUCTION

This type is excellent grazing land of low carrying capacity. Often grazing is almost as good during the drought period as during the growth period, since the dried vegetation remains

throughout the year and may be grazed at any time. As a consequence it supports a rich fauna of herbivora and also supplies pasturage for all types of domestic ruminants.

AGRICULTURE

Without irrigation this land has no value for crop production.

Desert Shrub

Fig. 37; *Db* on map

The desert-shrub formation is characterized by a scattered, evenly distributed growth of small plants which may be either woody or fleshy. As a rule the colors are not a bright green, and the whole presents, even during the growing season, the appearance of adjustment to drought conditions. The soil is usually bare between the plants, which are relatively far apart. At times this type presents the appearance of a forest of miniature trees, at other times of a miniature orchard; or the plants may be distributed so unequally that much of the surface is left almost bare of vegetation. The density of growth varies greatly in different portions of the formation and is an expression of the amount of water available for plant growth. In many sections the vegetation is composed largely of shrubby plants, the leaves of which are silvery in color and well protected either by a dense cuticle or by hairy surfaces. (In this aspect the African desert shrub resembles very closely portions of the sage-brush desert in the Great Basin region of the United States.) At other places, especially in the Karroo, the vegetation is made up largely of succulents with fleshy stems and fleshy leaves, often blending more or less with the color of the soil. (In this aspect it resembles very closely portions of the desert shrub of the southwestern United States where succulents abound.) During the short growth period when the plants are in flower the African desert shrub sometimes represents a mass of color greater than that of any other type, with the possible exception of the Cape flora. Over the greater desert stretches flowers seldom form a promi-

nent part of the landscape, but when they do they are usually yellow composites.

BOTANICAL DESCRIPTION

The desert shrub varies greatly in botanical composition. The Karroo is dominated largely by succulents and characterized for the most part by fleshy species of Mesembryanthemum, Lycium, and Pelargonium, while the Karroid plateau is characterized more largely by shrubby composites. Similar shrubs and even cushion forms occur in the north of Africa. Marloth (1910), who has made a special study of the Karroo, lists as important plants of this formation the following:

Aloe dichotoma L.
Euphorbia brachiata E. Meyer
Euphorbia gummifera Boiss.
Euphorbia cervicornis Boiss.
Euphorbia namibensis Marloth
Pteronia succulenta Thunb.
Pituranthos aphyllus (DC.) Kuntze
Mesembryanthemum fimbriatum Sond.
Mesembryanthemum opticum Marloth
Mesembryanthemum rhopalophyllum Schlecter & Diels
Mesembryanthemum moniliforme Thunb.
Augea capensis Thunb.
Pelargonium crassicaule L'Hérit.
Pelargonium cortusaefolium L'Hérit.
Sarcocaulon burmanni DC.
Othonna cacalioides L.
Crassula lycopodioides Lam.
Crassula deltoidea L.
Trichocaulon cactiformis N. E. Br.
Hoodia gordoni Sweet

On the Karroid plateau succulents are much less prominent. Here such desert shrubs as *Pentzia globosa* Less. and *Pentzia virgata* Less., known as Karroo bush, are more prominent. These

plants are especially prized because of their forage value. Another plant prominent here is *Rhigozum trichotomum* Burch., a plant which is covered with a mass of yellow flowers even before the rains begin. During much of the year this plant and the greater number of the other shrubs look perfectly dead. Here are also *Lycium arenicolum* Miers, Mesembryanthemum, and many other shrubby desert plants.

(Bolus 1905, Burchell, Evans 1920–21, Marloth 1905, 1908, 1910, Passarge 1904, H. H. W. Pearson 1910, 1911, L. Schultze 1907, Weiss 1906)

This type in the north is similar but usually not as luxuriant. Among the plants are the following:

Ephedra alata Decne
Anabasis aretoides Moq. & Coss.
Anabasis articulata Moq.
Balanites aegyptiaca Delile
Salvadora persica L.
Zizyphus lotus Lam.
Boscia senegalensis Lam.
Calotropis procera Dryand.
Genista raetam Forsk.
Artemisia herba-alba Asso
Artemisia campestris L.
Lygeum spartum Loefl.

(Almonte, Barth, Cannon, Chevalier 1900, Engler 1908, Ferrandi, Flahault, Schweinfurth 1868, Tilho 1910–14)

DISTRIBUTION

This type extends throughout the so-called desert region of South Africa and up along the western coast in a relatively narrow strip. In the region of the Sahara much of the vegetation is extremely sparse, but almost everywhere there are scattered a few desert shrubs, and therefore much of this region has been included in this type.

FIG. 37—Desert shrub. Scattered small desert shrubs. Much of the soil surface is bare. This is the Karroo bush (*Pentzia*) and is good forage. De Aar, Cape Province, Sept. 14, 1919.

FIG. 38.—Salt desert shrub. A scattered growth of green succulent-leaved plants (Salsola), typical of much of the wet salt-impregnated soils. Alexandersfontein, Cape Province, Sept. 25, 1919.

CLIMATIC CONDITIONS

The rainfall is low, ranging from 5 to 10 inches; and the drought period is long, from five to eight months. This drought period may be extended through many months or even years, although as a general rule rains should fall in this desert region during the summer months.

SOIL CONDITIONS

The soils are gray or reddish sandy desert soils, calcareous and entirely unleached.

NATURAL PRODUCTION

The only value of land of this type is for browse for camels, sheep, goats, horses, and ostriches. In the south especially an unusually large number of the desert shrubs are of value as forage, and in places the total growth is relatively great, making the land especially valuable for grazing.

AGRICULTURE

The land has no agricultural value unless placed under irrigation.

Salt Desert Shrub

Fig. 38; *Ds* on map

Where water comes to the surface slowly and then evaporates, it leaves behind soluble salts. These are usually referred to either as white or black alkali. White alkali is chiefly sodium chloride, sodium sulphate, magnesium sulphate, and magnesium chloride, which crystallize on the surface to form a white deposit. Black alkali is sodium carbonate, which corrodes organic matter and consequently leaves a dark deposit. Black alkali is much more harmful to vegetation than white alkali.

The salt desert shrub is usually composed of rather rich green, fleshy-leaved plants which grow in moist saline soil. The appearance is often that of luxuriant growth, but as a rule the plants are small and far apart. The soil surface is often white.

BOTANICAL DESCRIPTION

The principal species of this type are:

Salsola aphylla L.
Suaeda monoica Forsk.
Suaeda baccata Forsk.
Suaeda maritima Dum.
Suaeda vermiculata Forsk.
Salicornia fruticosa L.
Frankenia pulverulenta L.
Frankenia hirsuta L.

Where salt is less abundant, species of Tamarix occur.

DISTRIBUTION

This type occurs through the whole desert area and occasionally along the coast. It occurs in regions of relatively low rainfall.

AGRICULTURE

It has little value as grazing land and no value as agricultural or timber land. Without thorough drainage and leaching it has no agricultural potentialities.

(Bernard and Ficheur, Engler 1910)

Desert

Fig. 39; *Dd* on map

The desert is a waste of sand, rock, or soil surface, devoid or apparently devoid of vegetation throughout the year. Sand is often piled into dunes; while in other places the soil is entirely removed from the surface, leaving only the rock fragments which form a desert pavement. Here the polished (desert varnish) rocks are fitted together perfectly, forming a close pavement, leaving no soil visible. In still other places the rocky character of the surface leaves it composed only of rock ledges or rock masses. But even in these extremely arid areas there occasionally occur rains which moisten the surface soil. At such times

FIG. 39—A portion of the sandy desert, practically free of plant growth at this time. Although the locality where this photograph was taken is in the area called desert shrub on the map, it is illustrative of the true desert. Such patches occur throughout the desert shrub area, but are too small to be shown on the map. Station No. 4 on the Sudan Railway south of Wadi Halfa, Aug. 25, 1920.

seeds of rapid-growing, drought-escaping annuals germinate and occasionally reach maturity. Exceedingly drought-enduring, slow-growing perennials take advantage of the temporary available moisture to add to their storage supply or to push into a rapid growth, from which they soon relapse again into drought dormancy. The amount of plant growth is small, so small that it is often entirely overlooked; and the impression made on the traveler is that of extreme barrenness.

BOTANICAL DESCRIPTION

Although the desert is very poor in quantity of plant life measured by weight of matter produced, it is often a region rich in the number of species represented. During rain the seeds of almost all wind-borne annuals germinate; and many species may here be found, brought in from adjacent areas. The perennials are more limited and are confined to plants which can endure long periods of drought and can revive rapidly when water is again available or can resist drought by storage of a large supply of water (the succulents). The annuals may be said to evade the drought, the succulents to resist the drought, while other perennials endure the drought.

The great Namib Desert of Southwest Africa has attracted botanists partly on account of the remarkable conifer, *Welwitschia mirabilis* Hook. Other plants of importance are *Acanthosicyos horrida* Welw., a valuable source of food and water, *Salsola zeyheri* H. & B., *Sarcocaulon burmanni* DC., *Statice scabra* Thunb., and many other species.

In the stony desert portions of the Sahara *Lecanora esculenta* Eversm. occurs, and such desert plants as *Anabasis aretioides* Moq. & Coss., *Limoniastrum feei* Batt., and on the sandier areas *Ephedra alata* DC., *Aristida pungens* Desf., *Genista raetam* Forsk., and many other species.

(Brockmann-Jerosch and Heim, Brunhes, Dinter, Dove 1896, Duveyrier 1864, Engler 1910, Flahault, Lenz, 1881, Marloth 1908, 1910, Massart, Passarge

1904, H. H. W. Pearson 1907, 1909, 1910, 1911, Schirmer, L. Schultze 1907, Thomas, Vischer, Volkens 1887)

DISTRIBUTION

The greatest areas of desert lie in the Sahara, where immense areas are so destitute of vegetation that even camels cross them only when their food is transported as part of the caravan. In Southwest Africa the relatively narrow belt known as the Namib is true desert.

CLIMATIC CONDITIONS

The desert is extremely arid. The rainfall, from 1 to 5 inches, occurs at irregular periods. Drought may last from one to several years. Over portions of the desert, such as the western Sahara, fogs occur but are not often accompanied by rain. Temperatures range from a few degrees below freezing to 120° F., or more, and there is a very wide diurnal range.

SOIL CONDITIONS

The soils are gray, calcareous, and unleached.

NATURAL PRODUCTION

In the true desert there is no natural plant production, and the land has practically no value for grazing. There is no timber and no agriculture, and the crop potentiality is none unless irrigated, when desert lands become unusually productive.

LIST OF REFERENCES

Abruzzi, Luigi Amedeo, Duke of the. *See* De Filippi.

Adolf Friedrich, Duke of Mecklenburg-Schwerin. From the Congo to the Niger and the Nile: An account of the German Central African expedition of 1910–1911. 2 vols.; map, plates. London, 1913.

Ainsworth, John. A description of the Ukamba Province, East Africa Protectorate, and its progress under British administration. Map, ills. *Journ. Manchester Geogr. Soc.*, Vol. 16, 1900, pp. 178–196.

Aitken, R. D. The plant succession of a type of midland tree veld in Natal. Map, plates. *South African Journ. of Sci.*, Vol. 18, 1921–22, pp. 233–243. Johannesburg.

Aitken, R. D., and G. W. Gale. Botanical survey of Natal and Zululand. 19 pp. *Union of South Africa Botanical Survey, Memoir No. 2.* Pretoria, 1921.

Alexander, Boyd. From the Niger to the Nile. 2 vols.; maps, ills., plates. London, 1907.

Almonte, Enrique d'. Ensayo de una breve descripción del Sahara español. Maps, plates. *Bol. Real Soc. Geogr.*, Vol. 56, 1914, pp. 129–347. Madrid.

Ancelle, J. Les explorations au Sénégal et dans les contrées voisines depuis l'antiquité jusqu'à nos jours. 441 pp.; map. Paris, 1886.

Austin, H. H. (1901). Survey of the Sobat region. Map, ills. *Geogr. Journ.*, Vol. 17, 1901, pp. 495–512.

Austin, H. H. (1902). Among swamps and giants in equatorial Africa: An account of surveys and adventures in the Southern Sudan and British East Africa. 354 pp.; maps, plates. London, 1902.

Austin, H. H., and J. R. L. Macdonald. *See* Macdonald.

[Aylmer, L.] Captain Aylmer's journey in the country south of the Tana River, East Africa. Map. *Geogr. Journ.*, Vol. 32, 1908, pp. 55–59.

Ball, John, and H. J. L. Beadnell. Baharia oasis: Its topography and geology. 84 pp.; maps, diagrs. Egyptian Ministry of Public Works, Cairo, 1903.

Barth, Heinrich. Reisen und Entdeckungen in Nord- und Central-Afrika in den Jahren 1849 bis 1855 . . . 2 vols.; maps, ills., plates. Gotha, 1857. *See also* Petermann.

Bauer, Fritz. Die Deutsche Niger-Benue-Tsadsee Expedition 1902–1903. 182 pp.; maps, ills. Berlin, 1904.

Baum, H. Reisebericht. *In* Otto Warburg, edit.: Kunene-Sambesi-Expedition H. Baum 1903, pp. 1–153; map. Kolonial Wirtschaftliches Komitee, Berlin, 1903.

Baumann, Oscar. Durch Massailand zur Nilquelle: Reisen und Forschungen der Massai-Expedition des deutschen Antisklaverei-Komitee in den Jahren 1891–1893. 385 pp.; maps, ills., plates. Berlin, 1894.

Bayol, Jean. Voyage au pays de Bamako sur le haut Niger (Soudan occidental). *Bull. Soc. de Géogr. de Paris*, Ser. 7, Vol. 2, 1881, pp. 123–163.

Beadnell, H. J. L. (1901). Farafra oasis: Its topography and geology. 39 pp.; maps, diagrs. *Geol. Survey Rept., 1899, Part III.* Egyptian Ministry of Public Works, Cairo, 1901.

Beadnell, H. J. L. (1901a). Dakhla oasis: Its topography and geology. 107 pp.; maps, diagrs. *Geol. Survey Rept., 1899, Part IV.* Egyptian Ministry of Public Works, Cairo, 1901.

Beadnell, H. J. L., and John Ball. *See* Ball.

Bernard, Augustin, and Émile Ficheur. Les régions naturelles de l'Algérie. Maps, plates. *Ann. de Géogr.*, Vol. 11, 1902, pp. 221–246, 339–365, 419–437.

Bertin, André (1918). Les bois du Gabon. 304 pp.; maps, plates. (Mission Forestière Coloniale, Vol. 2.) Paris, 1918.

Bertin, André (1918a). Les bois de la Côte d'Ivoire. 176 pp.; maps, plates. (Mission Forestière Coloniale, Vol. 1.) Paris, 1918.

Bertin, André (1919). La question forestière coloniale. 833 pp.; maps, plates. (Mission Forestière Coloniale, Vol. 3.) Paris, 1919.

Bertin, André (1920). Les bois du Cameroun. 312 pp.; maps, plates. (Mission Forestière Coloniale, Vol. 4.) Paris, 1920.

Bews, J. W. (1909–13). The vegetation of Natal. Map, plates. *Annals Natal Museum*, Vol. 2, 1909–13, pp. 253–331.

Bews, J. W. (1916). An account of the chief types of vegetation in South Africa, with notes on the plant succession. *Journ. of Ecology*, Vol. 4, 1916, pp. 129–159.

Bews, J. W. (1917). The plant ecology of the Drakensberg range. Plates, *Annals Natal Museum*, Vol. 3, 1917, pp. 511–565.

Bews, J. W. (1917a). The plant succession in the thorn veld. Ills. *South African Journ. of Sci.*, Vol. 14, 1917, pp. 153–172.

Bews, J. W. (1918). The grasses and grasslands of South Africa. 161 pp.; map, ills. Pietermaritzburg, 1918.

Bieber, F. J. Das Hochland von Südäthiopien. Maps. *Petermanns Mitt.*, Vol. 54, 1908, pp. 1–15, 99–114.

Bindloss, Harold. In the Niger country. 338 pp.; maps. Edinburgh and London, 1898.

Blackburne-Maze, C. I. The flora of Mount Kenia, British East Africa. Ill. *The Gardeners Chronicle*, Ser. 3, Vol. 59, 1916, pp. 125–126.

Blaizot, Roger. L'agriculture au Tibesti. *Renseign. Colon.* (*Suppl. à l'Afrique Française*), 1918, pp. 243–247. Paris.

Blanc, Henry. From Metemma to Damot, along the western shores of the Tana Sea. Map. *Journ. Royal Geogr. Soc.*, Vol. 39, 1869, pp. 36–50.

Blundell, H. W. A journey through Abyssinia to the Nile. Map, ills. *Geogr. Journ.*, Vol. 15, 1900, pp. 97–121.

Bluzet, R. La région de Tombouctou. Map. *Bull. Soc. de Géogr. de Paris*, Ser. 7, Vol. 16, 1895, pp. 374–388.

Bolus, Harry (1893). The flora of South Africa. *In* John Noble, edit.: Illustrated official handbook of the Cape: A résumé of the history, conditions, populations, productions, and resources of the several colonies, states, and territories, pp. 91–123. Cape Town, 1893.

Bolus, Harry (1905). Sketch of the floral regions of South Africa. Map. *In* Science in South Africa: A handbook and review, edit. by W. Flint and J. D. F. Gilchrist, pp. 198–240. Cape Town, 1905.

Borelli, Jules. Éthiopie méridionale: Journal de mon voyage aux pays Amhara, Oromo et Sidama, septembre 1885 à novembre 1888. 520 pp.; maps, diagrs., ills., plates. Paris, 1890.

Bourg de Bozas. *See* Du Bourg de Bozas.

Bowdich, T. E. An account of the discoveries of the Portuguese in Angola and Mozambique. 186 pp.; maps. London, 1824.

Breschin, A. La forêt tropicale en Afrique, principalement dans les colonies françaises. Maps. *La Géographie*, Vol. 5, 1902, pp. 431–450; Vol. 6, 1902, pp. 27–39, 218–237.

Brockmann-Jerosch, Heinrich, and Arnold Heim. Vegetationsbilder vom Nordrand der algerischen Sahara. [10] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 6, No. 4. Jena, 1908.

Broun, A. F. Some notes on the "Sudd"-formation of the upper Nile. *Journ. Linnean Soc. of London*, Botany, Vol. 37, 1904–06, pp. 51–58.

Brown, Ernest, and H. H. Hunter. Planting in Uganda. 176 pp.; maps, ills., plates. London, 1913.

Browne, J. Penman. The Lado enclave and its commercial possibilities. *Scottish Geogr. Mag.*, Vol. 22, 1906, pp. 527–539.

Bruce, James. Travels to discover the source of the Nile, in the years 1768, 1769, 1770, 1771, 1772, and 1773. 5 vols.; maps, plates. Edinburgh, 1790.

Bruel, Georges. Les basses vallées de l'Oubangui et de la Sanga. *La Géographie*, Vol. 19, 1909, pp. 353–366.

Brunhes, Jean. Les oasis du Souf et du M'zab comme types d'établissements humains. Ill. *La Géographie*, Vol. 5, 1902, pp. 5–20, 175–195.

Büchner, Max. Die Büchner'sche Expedition. *Mitt. der Afrikanischen Gesell. in Deutschland*, Vol. 1, 1878–79, pp. 133–161, 222–246. Berlin.

Bunbury, C. J. F. Botanical excursions in South Africa. *The London Journ. of Botany*, Vol. 1, 1842, pp. 549–570; Vol. 2, 1843, pp. 15–41; Vol. 3, 1844, pp. 242–263.

Burchell, W. J. Travels in the interior of southern Africa. 2 vols.; map, ills., plates. London, 1822–24.

Burgt, J. M. M. van der (1903). Dictionnaire français-kirundi, avec l'indication succinte de la signification swahili et allemande. 648 pp.; maps, plates. Bois-le-Duc, 1903.

Burgt, J. M. M. van der (1906). Von Mwansa nach Uschirombo, 29. September bis 7. October 1903. Map. *Petermanns Mitt.*, Vol. 52, 1906, pp. 121–136.

Burton, R. F. The lake regions of Central Africa: A picture of exploration. 2 vols.; map, ills., plates. London, 1860.

Burtt Davy, Joseph (1903–05). Report of the government agrostologist and botanist. Maps, plates. *Ann. Rept. Transvaal Dept. of Agric.*, 1903–04, pp. 261–320; 1904–05, pp. 231–331. Pretoria.

Burtt-Davy, Joseph (1905–06). Comparative notes on the vegetation of Matabeleland, Bechuanaland, and the Transvaal. *Transvaal Agric. Journ.*, Vol. 4, 1905–06, pp. 134–141. Pretoria.

Burtt-Davy, Joseph (1905–06a). Notes on the native flora and crops of the low veld of eastern Transvaal. *Transvaal Agric. Journ.*, Vol. 4, 1905–06, pp. 141–147. Pretoria.

Burtt-Davy, Joseph (1905–06b). The climate and life zones of the Transvaal. *Transvaal Agric. Journ.*, Vol. 4, 1905–06, pp. 114–134, map, plates. Pretoria.

Büsgen, Moritz (1910). Vegetationsbilder aus dem Kameruner Waldland. [9] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 8, No. 7. Jena, 1910.

Büsgen, Moritz (1910a). Der Kameruner Küstenwald. Ills. *Zeitschr. für Forst- und Jagdwesen*, Vol. 42, 1910, pp. 264–283. Berlin.

Büsgen, Moritz (1920). Articles in Schnee, Heinrich, edit. which see.

Büsgen, Moritz, and Fritz Jentsch. *See* Jentsch, Fritz, and Moritz Büsgen.

Busse, Walter (1900–01). Expedition nach den deutsch-ostafrikanischen Steppen. Bericht I–VII. Ills. Kolonial Wirtschaftliches Komitee, Berlin [1900–01].

Busse, Walter (1901). Über Verlauf und Ergebnisse meiner Reisen in Deutsch-Ostafrika. *Ber. Deut. Pharm. Gesell.*, Vol. 11, 1901, pp. 408–435.

Busse, Walter (1905). Über einige Ergebnisse meiner Reise nach Togo und Kamerun. Plates. *Ber. Deut. Pharm. Gesell.*, Vol. 15. 1905, pp. 205–225.

Busse, Walter (1907). Das südliche Togo. [18] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 4, No. 2. Jena, 1907.

BUSSE, WALTER (1907a). Deutsch-Ostafrika, I: Zentrales Steppengebiet. [18] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 5, No. 7. Jena, 1907.

BUSSE, WALTER (1908). Deutsch-Ostafrika, II: Ostafrikanische Nutzpflanzen. [12] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 6, No. 7. Jena, 1908.

BUSSE, WALTER (1908a). Die periodischen Grasbrände im tropischen Afrika, ihr Einfluss auf die Vegetation und ihre Bedeutung für die Landeskultur. Ills. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 21, 1908, pp. 113–139.

BUSSE, WALTER (1920). Articles in SCHNEE, HEINRICH, edit., which see.

CAMERON, V. L. Across Africa. 2 vols.; map, ills., plates. London, 1877.

CANNON, W. A. Botanical features of the Algerian Sahara. 81 pp.; map, plates. *Carnegie Instn. Publ. No. 178*. Washington, D. C., 1913.

CAPELLO, HERMENGILDO, and R. IVENS. From Benguella to the territory of Yacca. Description of a journey into Central and West Africa. 2 vols.; maps, ills. London, 1882.

CARPENTER, L. O., and ALEXANDER HOLM. Report on the agricultural census of the Colony and Protectorate of Kenya. Nairobi, 1921.

CHAPIN, J. P. Migration of birds in Africa. Maps. *Amer. Museum Journ.*, Vol. 16, 1916, pp. 540–545. New York.

CHEVALIER, AUGUSTE (1900). La végétation de la région de Tombouctou. Ills. *Actes du 1er Congr. Internatl. de Bot., Paris, 1900*, pp. 248–275.

CHEVALIER, AUGUSTE (1907). L'Afrique centrale française: Récit du voyage de la mission (Mission Chari-Lac Tchad 1902–1904). 776 pp.; maps, ills., plates. Paris, 1907.

CHEVALIER, AUGUSTE (1909). Les massifs montagneux du nord-ouest de la Côte d'Ivoire. *La Géographie*, Vol. 20, 1909, pp. 207–224.

CHEVALIER, AUGUSTE (1909a). Dans le nord de la Côte d'Ivoire: Mission scientifique de l'Afrique occidentale française (18 février au 7 avril, 1909). *La Géographie*, Vol. 20, 1909, pp. 25–29.

CHEVALIER, AUGUSTE (1909b). La région des sources du Niger: Mission scientifique de l'Afrique occidentale française (1909). Map, ills. *La Géographie*, Vol. 19, 1909, pp. 337–352.

CHEVALIER, AUGUSTE (1909c). Les hauts plateaux du Fouta Djalon. Plates. *Ann. de Géogr.*, Vol. 18, 1909, pp. 253–261.

CHEVALIER, AUGUSTE (1909d). Première étude sur les bois de la Côte d'Ivoire. 314 pp.; map. (Les végétaux utiles de l'Afrique tropicale française, Vol. 5.) Paris, 1909.

CHEVALIER, AUGUSTE (1910). Le pays des Hollis et les régions voisines. Mission scientifique de l'Afrique occidentale française (1910). *La Géographie*, Vol 21, 1910, pp. 427–433.

CHEVALIER, AUGUSTE (1912). Les richesses du Congo français: La valeur des territoires cédés à l'Allemagne, l'avenir des territoires que nous gardons. Map. *Rev. Gén. des Sci.*, Vol. 23, 1912, pp. 497–506.

CHEVALIER, AUGUSTE (1916). La forêt et les bois du Gabon. 468 pp., ills., 28 plates. (Les végétaux utiles de l'Afrique tropicale française, Vol. 9.) Paris, 1916.

CHEVALIER, AUGUSTE (1920). Exploration botanique de l'Afrique occidentale française, Vol. 1: Énumération des plantes récoltées. 798 pp.; map. Paris, 1920.

CHUDEAU, RENÉ. Le bassin du moyen Niger. Maps, ills. *La Géographie*, Vol. 21, 1910, pp. 389–408.

CHUDEAU, RENÉ, and ABEL GRUVEL. *See* GRUVEL and CHUDEAU.

CHURCHILL, W. A. The Sugar-Loaf Mountain, Mozambique. *Geogr. Journ.*, Vol. 4, 1894, pp. 352–355.

COMBES, EDMOND, and MAURICE TAMISIER. Voyage en Abyssinie, dans le pays des Galla, de Choa, et d'Ifat; précédé d'une excursion dans l'Arabie heureuse, et accompagné d'une carte de ces diverses contrées. 4 vols.; map. Paris, 1838.

COSSON, M. E. Le règne végétal en Algérie. *Rev. Scientifique*, Vol. 23, 1879, pp. 1205–1217. Paris.

COTTES, A. La Guinée espagnole. Maps. *Ann. de Géogr.*, Vol. 18, 1909, pp. 433–450.

D'ALMONTE. *See* ALMONTE.

DALZIEL, J. M. Vegetable products of Kontagora Province, Northern Nigeria. *Bull. Imperial Inst.*, Vol. 5, 1907, pp. 255–266. London.

DANIEL, J. Le palmier à huile au Dahomey. *Rev. Coloniale*, Vol. 1 (N.S.) 1901, pp. 187–205, 360–374.

DECKEN, C. C. VON DER. Baron Carl Claus von der Decken's Reisen in Ost-Afrika in den Jahren 1859 bis 1865. Bearb. von O. Kersten, etc. 4 vols. in 6; maps, ills., plates. Leipzig and Heidelberg, 1869–79.

DE FILIPPI, FILIPPO. Ruwenzori: An account of the expedition of H.R.H. Prince Luigi Amedeo of Savoy, Duke of the Abruzzi. 407 pp.; maps, ills., plates. London, 1909. [Transl. from the Italian.]

DE GREEF, GUILLAUME. Monographie agricole de la région de l'Urundi, ancienne province de l'Afrique orientale allemande. Map, ills. *Bull. Agric. du Congo Belge*, Vol. 10, 1919, pp. 3–69.

DE MATHUISIEULX, H. M. *See* MATHUISIEULX.

DE SANDERVAL, OLIVER. *See* SANDERVAL.

DICKENS, VINCENT. Journeys in south-eastern Mashonaland. Map. *Geogr. Journ.*, Vol. 29, 1907, pp. 15–23.

DIELS, LUDWIG. Formationen und Florenelemente im nordwestlichen Kapland. Map. *Botanische Jahrbücher*, Vol. 44, 1909, pp. 91–124.

DIMOTHÉOS, —. Deux ans de séjour en Abyssinie; ou vie morale, politique et religieuse des Abyssiniens. 2 vols. in 1. Jerusalem, 1871.

DINTER, KURT. Deutsch-Südwest-Afrika: Flora, forst- und landwirtschaftliche Fragmente. 191 pp.; plates. Leipzig, 1909.

DOCHARD, —. *See* GRAY.

D'OLLONE, H. M. G. VICOMTE. *See* OLLONE.

DOVE, KARL (1890). Kulturzonen von Nord-Abessinien. 34 pp.; map. *Petermanns Mitt. Ergänzungsheft No. 97.* Gotha, 1890.

DOVE, KARL (1896). Deustch-Südwest-Afrika: Ergebnisse einer wissenschaftlichen Reise im südlichen Damaralande. 93 pp.; map. *Petermanns Mitt. Ergänzungsheft No. 120.* Gotha, 1896.

DOVE, KARL (1903). Deutsch-Südwest-Afrika. 208 pp.; map, ills. (Süsserott's Kolonialbibliothek, Vol. 5.) Berlin, 1903.

DRAKE-BROCKMAN, R. E. The economic resources of British Somaliland. *Trans. 3d Internatl. Congr. of Topical Agric., Held at the Imperial Inst., London, S. W., June 3rd to 30th, 1914,* Vol. 2, pp. 488–500. London, 1917.

DU BOURG DE BOZAS, R.M.P., VICOMTE. Mission scientifique Du Bourg de Bozas. De la Mer Rouge à l'Atlantique à travers l'Afrique tropicale (octobre 1900–mai 1903). 442 pp.; maps, ills., plates. Paris, 1906.

DUDGEON, G. C. The agricultural and forest products of British West Africa. 170 pp.; maps, plates. (Imperial Inst. Handbooks.) London, 1911.

DUFOUR, G. Rapport de délimitation franco-portugaise de la Commission entre le Congo et le Cabinda. Map. *Rev. Coloniale,* Vol. 1 (N.S.), 1902, pp. 607–624.

DUNDAS, E. G. Expedition up the Jub River through Somali-land, East Africa. Map. *Geogr. Journ.,* Vol. 1, 1893, pp. 209–223.

DU PLESSIS, J. Thrice through the dark continent: A record of journeyings across Africa during the years 1913–16. 350 pp.; maps, plate. London, 1917.

DUVEYRIER, HENRI (1864). Exploration du Sahara: Les Toureg du nord. 499 pp.; map, plates. Paris, 1864.

DUVEYRIER, HENRI (1893). De Telemsan à Melila en 1886. Map. *Bull. Soc. de Géogr. de Paris,* Ser. 7, Vol. 14, 1893, pp. 185–222.

DYBOWSKI, JEAN. La route du Tchad du Loango au Chari. 381 pp.; map, ills., plates. Paris, 1893.

DYÉ, A. H. Le Bahr el Ghazal: Notions générales sur la province, les rivières, les plateaux et les marais. Maps, plates. *Ann. de Géogr.,* Vol. 11, 1902, pp. 315–338.

ECKERSLEY, W. A. Notes on eastern Mashonaland. Diagr., ills. *Geogr. Journ.,* Vol. 5, 1895, pp. 27–46.

ELLIOT, G. F. S. Notes on the regional distribution of the Cape flora. *Trans. Botanical Soc. of Edinburgh,* Vol. 18, 1889–90, pp. 241–251.

ELLIOTT, F. Jubaland and its inhabitants. Map, plates. *Geogr. Journ.,* Vol. 41, 1918, pp. 554–561.

EMIN PASHA (EDUARD SCHNITZER). Reisen im Osten des Bahr-el-Djebel, März bis Mai 1881. Maps. *Petermanns Mitt.*, Vol. 28, 1882, pp. 259–272, 321–329.

ENGLER, ADOLF (1891). Über die Hochgebirgsflora des tropischen Afrika. 461 pp. *Abhandl. Königl. Akad. der Wiss. zu Berlin, Phys.-Math. Cl. II.*, 1891.

ENGLER, ADOLF (1893). Über die Flora des Gebirgslandes von Usambara, auf Grund der von Herrn Carl Holst daselbst gemachten Sammlungen. *Botanische Jahrbücher*, Vol. 17, 1893, pp. 156–168.

ENGLER, ADOLF (1894). Über die Gliederung der Vegetation von Usambara und der angrenzenden Gebiete. *Abhandl. Königl. Akad. der Wiss. zu Berlin*, 1894, No. 1, pp. 1–86.

ENGLER, ADOLF (1895). Die Pflanzenwelt Ost-Afrikas und der Nachbargebiete. 3 vols. in 2, ills., plates. (Deutsch-Ost-Afrika: Wissenschaftliche Forschungsresultate über Land und Leute unseres ostafrikanischen Schutzgebietes und der angrenzenden Länder, Vol. 5.) Berlin, 1895.

ENGLER, ADOLF (1900). Über die Vegetationsverhältnisse des Ulugurugebirges in Deutsch-Ostafrika. *Sitzungsber. Königl. Preuss. Akad. der Wiss.*, Berlin, 1900, pp. 191–211.

ENGLER, ADOLF (1902). Über die Vegetationsverhältnisse des in Norden des Nyassa-Sees gelegenen Gebirgslandes. *Sitzungsber. Königl. Preuss. Akad. der Wiss.*, Berlin, 1902, pp. 215–236.

ENGLER, ADOLF (1906). Beiträge zur Kenntniss der Pflanzenformationen von Transvaal und Rhodesia. *Sitzungsber. Königl. Preuss. Akad. der Wiss.*, Berlin, 1906, pp. 866–906.

ENGLER, ADOLF (1908). Pflanzengeographische Gliederung von Afrika. *Sitzungsber. Königl. Preuss. Akad. der Wiss.*, Berlin, 1908, pp. 781–837.

ENGLER, ADOLF (1909–1910). Bemerkungen zur Vegetationskarte von Deutsch-Ostafrika. 4 pp. with map. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 1.

ENGLER, ADOLF (1909–10a). Bemerkungen zur Vegetationskarte von Kamerun. 4 pp. with map. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 1.

ENGLER, ADOLF (1909–10b). Bemerkungen zur Vegetationskarte von Togo. 2 pp. with map. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 2.

ENGLER, ADOLF (1909–10c). Bemerkungen zur Vegetationskarte von Deutsch-Südwestafrika. 2 pp. with map. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 2.

ENGLER, ADOLF (1910). Die Pflanzenwelt Afrikas, insbesondere seiner tropischen Gebiete: Grundzüge der Pflanzenverbreitung in Afrika und die Charakterpflanzen Afrikas. 3 vols. in 4. Vol. 1, Allgemeiner Überblick über die Pflanzenwelt Afrikas und ihre Existenzbedingungen.

2 halves; maps, ills., plates. (Die Vegetation der Erde: Sammlung pflanzengeographischer Monographien, herausg. von A. Engler und O. Drude, Vol. 9.) Leipzig, 1910.

Esch, Ernst. Über das Küstengebiet von Kamerun auf Grund zweijähriger Reisen. *Verhandl. Gesell. für Erdkunde zu Berlin*, Vol. 27, 1900, pp. 272–285.

Evans, I. B. Pole (1918). The plant geography of South Africa. 8 pp.; map, plates. Reprinted from the official year book, 1917. Pretoria, 1918.

Evans, I. B. Pole (1920–21). The veld: Its resources and dangers. Plates. *South African Journ. of Sci.*, Vol. 17, 1920–21, pp. 1–34.

Faber, F. C. von. Vegetationsbilder aus Kamerun. Plates. *Beih des Botanischen Centralblatt*, Vol. 23, 1908, 2nd Section, pp. 26–42.

Fabert, Léon. Voyage dans le pays des Trarzas et dans le Sahara occidental. Map. *Bull. Soc. de Géographie de Paris*, Ser. 7, Vol. 13, 1892, pp. 375–392.

Falkenstein, Julius. *See* Güssfeldt.

Farini, G. A. Through the Kalahari desert: A narrative of a journey with gun, camera, and note-book to Lake N'Gami and back. 475 pp.; map, ills., plates. London, 1886.

Ferrandi, Jean. Description du Borkou méridional. Ills. *Bull. Soc. de Géogr. Commerc. de Paris*, Vol. 36, 1914, pp. 523–558.

Ferret, P. V. A., and J. G. Galinier. Voyage en Abyssinie. 3 vols. and atlas. Paris, 1847–48.

Ficheur, Émile. *See* Bernard.

Filippi. *See* De Filippi.

Fischer, G. A. Am Ostufer des Victoria-Njansa. Map. *Petermanns Mitt.*, Vol. 41, 1895, pp. 1–6, 42–46, 66–72.

Fishbourne, C. E. Lake Kioga (Ibrahim) exploratory survey, 1907–1908. *Geogr. Journ.*, Vol. 33, 1909, pp. 192–195.

Fitzsimons, F. W. The natural history of South Africa. 4 vols.; plates. London, 1919–1920.

Flahault, Charles. Rapport sur les herborisations de la Société. Plates. *Bull. Soc. Botanique de France*, Vol. 53, 1906, pp. lxxxviii–clxxix.

Flahault, Charles, and Carl Schröter. Rapport sur la nomenclature phytogéographique. *Actes du 3me Congr. Internatl. Botanique, Bruxelles, 1910*, Vol. 1, pp. 131–162.

Floyer, E. A. Further routes in the eastern desert of Egypt. Ills. *Geogr. Journ.*, Vol. 1, 1893, pp. 408–431.

Foureau, Fernand (1901). From Algeria to the French Congo. Map, ills. *Geogr. Journ.*, Vol. 17, 1901, pp. 135–150. [Abridgment of paper read at Paris Geographical Society, Dec. 5, 1900.]

FOUREAU, FERNAND (1905). Documents scientifiques de la mission saharienne (Mission Foureau-Lamy "d'Alger au Congo par le Tchad") 4 vols.; maps, ills., plates. Paris, 1905.

FREY, GISELA (1914). Der Njassasee und das deutsche Njassaland: Versuch einer Landeskunde. Preisgekrönt von der Deutschen Kolonial Gesellschaft. 64 pp.; maps. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 10.* Berlin, 1914.

FREY, GISELA (1916). Beiträge zur Landeskunde Deutsch-Ostafrikas. *Zeitschr. Gesell. für Erdkunde zu Berlin*, 1916, pp. 505–543.

FREYDENBERG, HENRI. Étude sur le Tchad et le bassin du Chari. 187 pp.; maps, diagrs., ills. Paris, 1908.

FRIES, R. E. (1913). Die Vegetation des Bangweologebietes. Map, ills. *Svensk Botanisk Tidskrift*, Vol. 7, 1913, pp. 233–257. Stockholm, 1913.

FRIES, R. E. (1914). Vegetationsbilder aus dem Bangweologebiet, Nordost-Rhodesia. [13] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 12, No. 1. Jena, 1914.

FRIES, R. E. (1921). Botanische Untersuchungen: Ergänzungsheft. 135 pp.; ills., plates. Wissenschaftliche Ergebnisse der schwedischen Rhodesia-Kongo-Expedition 1911–1912 unter Leitung von Eric Graf von Rosen, Vol. 1. Stockholm, 1921.

FROBENIUS, LEO. Im Schatten des Kongostaates. Bericht über den Verlauf der ersten Reise der D. I. A. F. E. von 1904–1906, über deren Forschungen und Beobachtungen auf geographischem und kolonial-wirtschaftlichem Gebiet. 468 pp.; maps, ills., plates. Berlin, 1907.

FUCHS, PAUL. Die wirtschaftliche Erkundung einer ostafrikanischen Südbahn. Maps, ills., plates. *Tropenpflanzer Beiheft No. 6*, 1905, pp. 219–410.

FÜLLEBORN, FRIEDRICH. Über seine Reisen im Nyassa-Gebiet. *Verhandl. Gesell. für Erdkunde zu Berlin*, Vol. 27, 1900, pp. 371–384.

FYFFE, R. Forestry in Uganda. Statement prepared for the British Empire Forestry Conference, London, 1920. 8 pp.

GALINIER, J. G. *See* FERRET.

GARDE, G. Les régions au nord-est du Tchad (Mission de délimitation Niger-Tchad—Mission Tilho). Map. *La Géographie*, Vol. 21, 1910, pp. 237–244.

GARSTIN, SIR W. E. Notes on the Soudan. 46 pp. Ministry of Public Works, Cairo, 1899.

GAUTIER, E. F. À travers le Sahara français d'In Ouzel au Niger. Diagr. *La Géographie*, Vol. 15, 1907, pp. 1–28, 103–120.

GIBBONS, A. ST. H. (1904). Africa from south to north through Marotseland. 2 vols.; maps, plates. London and New York, 1904.

GIBBONS, A. ST. H. (1906). British East African plateau land and its economic conditions. Map. *Geogr. Journ.*, Vol. 27, 1906, pp. 242–257.

GIBBONS, A. ST. H. (1907). The transition of British Africa. Ills. *Scottish Geogr. Mag.*, Vol. 23, 1907, pp. 122–141.

GIBBS, L. S. A contribution to the botany of Southern Rhodesia. Plates. *Journ. Linnean Soc. of London*, Botany, Vol. 37, 1904–06, pp. 425–494.

GINDRE, HENRI. En Afrique australe et à Madagascar. *Bull. Soc. de Géogr. de Lyon*, Vol. 14, 1896–1898, pp. 319–374.

GLEICHEN, LORD EDWARD (1898). Report on the Nile and country between Dongola, Suakin, Kassala, and Omdurman. Compiled in the Intelligence Division, War Office. 2nd edit., 338 pp.; maps. London, 1898.

GLEICHEN, LORD EDWARD, edit. (1905). The Anglo-Egyptian Sudan: A compendium prepared by officers of the Sudan government. 2 vols.; maps, ills., plates. London, 1905.

GOETZE, WALTHER. Bericht über seine Reise von Dar-es-Salâm nach Kisaki. *Botanische Jahrbücher*, Vol. 27, 1900, pp. 222–228.

GORGES, G. H. A journey from Lake Naivasha to the Victoria Nyanza. Map, ills. *Geogr. Journ.*, Vol. 16, 1900, pp. 78–89.

GÖTZEN, G. A., COUNT VON. Durch Afrika von Ost nach West. Resultate und Begebenheiten einer Reise von der Deutsch-Ostafrikanischen Küste bis zur Kongomündung in den Jahren 1893–94. 416 pp.; map, ills. Berlin, 1895.

GRAY, WILLIAM, and Staff Surgeon DOCHARD. Travels in western Africa, in the years 1818, 1819, 1820, and 1821, from the River Gambia, through Woolli, Bondoo, Galam, Kasson, Kaarta, and Foolidoo, to the River Niger. 413 pp.; map, plates. London, 1825.

GREEF. *See* DE GREEF.

GREGORY, J. W. (1894). Contributions to the physical geography of British East Africa. Maps, diagrs. *Geogr. Journ.*, Vol. 4, 1894, pp. 289–315, 408–424, 505–524.

GREGORY, J. W. (1896). The Great Rift valley: Being the narrative of a journey to Mount Kenya and Lake Baringo, with some account of the geology, natural history, anthropology, and future prospects of British East Africa. 422 pp.; maps, ills., plates.

GRIMME, C. *See* HEERING.

GROGAN, E. S. Through Africa from the Cape to Cairo. Maps, ills. *Geogr. Journ.*, Vol. 16, 1900, pp. 164–185.

GRUVEL, ABEL. Observations géographiques sur la Mauritanie occidentale. Map, ills. *La Géographie*, Vol. 20, 1909, pp. 1–8.

GRUVEL, ABEL, and RENÉ CHUDEAU. À travers la Mauritanie occidentale (de Saint-Louis à Port Étienne). 2 vols.; maps, plates. Paris, 1909–1911.

GUGGISBERG, F. G. Handbook of the Southern Nigeria survey and text book of topographical surveying in tropical Africa. 246 pp.; maps, diagrs., ills. Edinburgh, 1911.

Güssfeldt, Paul, Julius Falkenstein, and Eduard Pechuel-Loesche. Die Loango-Expedition ausgesandt von der Deutschen Gesellschaft zur Erforschung Aequatorial-Africas 1873–76. 3 vols. in 4; maps, ills., plates. Leipzig, 1879, 1879, 1882, and Stuttgart, 1906.

Gwynn, C. W. A journey in southern Abyssinia. Map, plates. *Geogr. Journ.*, Vol. 38, 1911, pp. 113–139.

Hagen, H. B. Das algerisch-tunesische Atlasgebirge. [17] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 10, No. 1–3, Section 1. Jena, 1913.

Hahn, Friedrich. Afrika. *In* Allgemeine Länderkunde, edit. by Wilhelm Sievers. 2nd edit. of "Afrika" by Wilhelm Sievers, Leipzig, 1895. 681 pp.; maps, ills., plates. Leipzig, 1901.

Hallé, Clifford. To Menelik in a motor-car. 312 pp.; map, plates. London, 1913.

Hamilton, Agnus. Somaliland. 366 pp.; map, plates. London, 1911.

Harris, W. C. The highlands of Ethiopia. 3 vols.; map, plates. London, 1844.

Hartmann, Robert. Abyssinien und die übrigen Gebiete der Ostküste Afrikas. 304 pp.; ills. (Das Wissen der Gegenwart. Deutsche Universal-Bibliothek für Gebildete, Vol. 14.) Leipzig, 1883.

[Hassert, Kurt] (1908). Berichte über die landeskundliche Expedition der Herren K. Hassert und F. Thorbecke. Maps. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 21, 1908, pp. 1–12, 157–162, 189–199.

Hassert, Kurt (1917). Beiträge zur Landeskunde der Grashochländer Nordwest-Kameruns. Part I: Physische Geographie. 144 pp.; maps, plates. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 13*. Berlin, 1917.

Hayes, A. J. The source of the Blue Nile. 315 pp.; maps, plates. London, 1905.

Haywood, A. H. W. Through Timbuctu and across the great Sahara: An account of an adventurous journey of exploration from Sierra Leone to the source of the Niger, following its course to the bend at Gao and thence across the great Sahara to Algiers. 349 pp.; maps, plates. London and Philadelphia, 1912.

Hecquard, L. Hyacinte. Voyage sur la côte et dans l'intérieur de l'Afrique occidentale. 409 pp.; maps, plates. Paris, 1853.

Heering, Wilhelm, and C. Grimme. Untersuchungen über die Weideverhältnisse in Deutsch-Südwestafrika. 14 3pp. *Arb. Deut. Landw. Gesell. 197*. 1911.

Heim, Arnold. *See* Brockmann-Jerosch.

Heller, Edmund. *See* Roosevelt.

Henrique, Louis. Colonies d'Afrique: Sénégal et rivières du Sud—Soudan français. 366 pp.; map, ills. (Les colonies françaises: Notices illustrées, Vol. 5.) Paris, [1890].

HEUGLIN, THEODOR VON (1857). Reisen in Nord-Ost-Afrika. . . . Chartum nach Abyssinien. 136 pp.; map. ills., plates. Gotha, 1857.

[HEUGLIN, THEODOR VON] (1862). Reise der Herren Th. v. Heuglin, Dr. Steudner und H. Schubert von Djenda in Abessinien nach Chartum, Mai und Juni 1862. *Petermanns Mitt.*, Vol. 8, 1862, pp. 381–387.

HILTON-SIMPSON, M. W. Land and peoples of the Kasai. 356 pp.; map, plates. London, 1911.

HINDE, S. L. Three years' travel in the Congo Free State. Map, ills. *Geogr. Journ.*, Vol. 5, 1895, pp. 426–446.

HOBLEY, C. W. People, places, and prospects in British East Africa. Ill. *Geogr. Journ.*, Vol. 4, 1894, pp. 97–123.

HOCK, A. L'agriculture au Katanga: Possibilités et réalités. 305 pp.; map, plates. (Missions dans le Katanga, Vol. 2.) Brussels, 1912.

HODSON, A. W. Trekking the great thirst: Travel and sport in the Kalahari Desert. 359 pp.; maps, plates. London, 1912.

HÖHNEL, LUDWIG VON. Ostäquatorial-Afrika zwischen Pangani und dem neuentdeckten Rudolf-See. Ergebnisse der Graf S. Telekischen Expedition 1887–88. 44 pp.; maps. *Petermanns Mitt. Ergänzungsheft No. 99*. Gotha, 1890.

HOLM, ALEXANDER. *See* CARPENTER.

HOPE, C. W. The "sudd" of the upper Nile: Its botany compared with that of similar obstructions in Bengal and American waters. *Annals of Botany*, Vol. 63, 1902, pp. 495–516. London.

HORE, E. C. Lake Tanganyika. *Proc. Royal Geogr. Soc.*, Vol. 4, 1882, pp. 1–28.

HOTTEN, J. C. Abyssinia and its people; or, life in the land of Prester John. 384 pp.; map, plates. London, 1868.

HULOT, [ÉTIENNE.] Carte botanique, forestière et pastorale de l'Afrique occidentale française. Carte dressée sous la direction de A. Chevalier. *La Géographie*, Vol. 26, 1912, pp. 276–277.

HUMPHRIES, A. E. The production of wheat in the tropics. *Trans. 3rd Internatl. Congr. of Tropical Agric. Held at the Imperial Inst., London, June 23–30, 1914*, Vol. 2, pp. 1–19. London, 1917.

HUNTER, H. H. *See* BROWN, ERNEST.

HUPFELD, F. Palmöl in den deutschen Kolonien. Diagr. *Trans. 3rd Internatl. Congr. of Toprical Agric. Held at the Imperial Inst., London, June 23–30, 1914* Vol. 2, pp. 281–300. London, 1917.

HUTCHINS, D. E. (1893). South African woods and forests. Ills. *In* John Noble, edit.: Illustrated official handbook of the Cape, and South Africa: A résumé of the history, conditions, populations, productions, and resources of the several colonies, states, and territories, pp. 124–137. Cape Town, 1893.

HUTCHINS, D. E. (1905). Forestry in South Africa. Ills. *In* Science in South Africa: A handbook and review, edit. by W. Flint and J. D. F. Gilchrist, pp. 391–413. Cape Town, 1905.

HUTCHINS, D. E. (1907). Report on the forests of Kenia. 39 pp. *Misc. Colonial Repts. No.* 41. Cd. 3561. H. M. Stationery Office, London, 1907.

HUTCHINS, D. E. (1909). Report on the forests of British East Africa. 155 pp.; map, ills. Cd. 4723. H. M. Stationery Office, London, 1909.

IVENS, R. *See* CAPELLO.

JAEGER, FRITZ (1909). Forschungen in den Hochregionen des Kilimandscharo. Maps, diagrs., plates. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 22, 1909, pp. 114–146, 161–197.

JAEGER, FRITZ (1911–13). Das Hochland der Riesenkrater und die umliegenden Hochländer Deutsch-Ostafrikas. Ergebnisse einer amtlichen Forschungsreise ins abflusslose Gebiet des nördlichen Deutsch-Ostafrika 1906–07. Part I. 133 pp.; maps, diagrs., plates. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 4.* Berlin, 1911. Part II. 213 pp.; maps, diagrs., plates. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 8.* Berlin, 1913.

JAMES, F. L. The unknown horn of Africa: An exploration from Berbera to the Leopard River. 344 pp.; maps, ills., plates. London, 1888.

JENTSCH, FRITZ. Der Urwald Kameruns: Folgerungen aus den auf der Expedition 1908–1909 gewonnenen Erfahrungen in bezug auf den Zustand und die Nutzbarmachung des Waldes. Plates. *Tropenpflanzer Beiheft No. 12*, 1911, pp. 1–199.

JENTSCH, FRITZ, and MORTIZ BÜSGEN. Forstwirtschaftliche und forstbotanische Expedition nach Kamerun und Togo. Map, ills., plates. *Tropenpflanzer Beiheft No. 10*, 1909, pp. 185–310.

JESSEN, B. H. South-western Abyssinia. Map, ills. *Geogr. Journ.*, Vol. 25, 1905, pp. 158–171.

JOHNSTON, CHARLES. Travels in southern Abyssinia, through the country of Adal to the kingdom of Shoa. 2 vols.; map, plates. London, 1844.

JOHNSTON, SIR H. H. (1886). The Kilima-Njaro expedition: A record of scientific exploration in eastern equatorial Africa and a general description of the natural history, languages, and commerce of the Kilima-Njaro district. 572 pp.; maps, plates. London, 1886.

JOHNSTON, SIR H. H. (1895). The British Central Africa Protectorate. Map, ills. *Geogr. Journ.*, Vol. 5, 1895, pp. 193–218.

JOHNSTON, SIR H. H. (1902). The Uganda protectorate: An attempt to give some description of the physical geography, botany, zoology, anthropology, languages, and history of the territories under British protection in East Central Africa, between the Congo Free State and the Rift Valley and between the first degree of south latitude and the fifth degree of north latitude. 2 vols.; maps, ills., plates. London, 1902.

JOHNSTON, SIR H. H. (1905). Liberia. Map, ills. *Geogr. Journ.*, Vol. 26, 1905, pp. 131–151. Reprinted in *Ann. Rept. Smithsonian Instn. for 1905*, pp. 247–264. [The plates of the reprint are not the same as those of original.]

JOHNSTON, SIR H. H. (1906). Liberia. With an appendix on the flora of Liberia by Dr. Otto Stapf. 2 vols.; maps, ills., plates. London, 1906.

JOHNSTON, SIR H. H. (1908). George Grenfell and the Congo: A history and description of the Congo independent state and adjoining districts of Congoland, etc. 2 vols.; maps, ills., plates. London, 1908.

JULIEN, E. P. F. Du Haut-Oubangui vers le Chari par le bassin de la rivière Kota (1 mai–5 octobre, 1894). Map. *Bull. Soc. de Géogr. de Paris*, Ser. 7, Vol. 18, 1897, pp. 129–178, 340–384, 496–518.

JUNKER, WILHELM (1877). Bericht über eine Fahrt auf dem Sobat. Map. *Zeitschr. Gesell. für Erdkunde zu Berlin*, Vol. 12, 1877, pp. 1–7.

[JUNKER, WILHELM] (1888–89). Wissenschaftliche Ergebnisse von Dr. W. Junkers Reisen in Zentral-Afrika 1880–1885. 114 pp.; maps. *Petermanns Mitt. Ergängzungsheft Nos. 92–93*. Gotha, 1888–89.

JUNOD, H. A. The life of a South African tribe. 2 vols.; ills. London, 1913.

KANDT, RICHARD. Caput Nili: Eine empfindsame Reise zu den Quellen des Nils. 538 pp.; map, plates. Berlin, 1904.

KARSTEN, GEORG. Über die Mangrove-Vegetation im Malayischen Archipel. 71 pp.; plates. *Bibliotheca Botanica, No. 22*. Cassel, 1891.

KASSNER, THEODORE. My journey from Rhodesia to Egypt, including an ascent of Ruwenzori and a short account of the route from Cape Town to Broken Hill and Lado to Alexandria. 308 pp.; maps, plates. London, 1911.

KENYA COLONY. Colony and Protectorate of Kenya. Agricultural census, 1920. First report. 37 pp.; map. Nairobi, 1921.

KERR-CROSS, D. Crater-lakes north of Lake Nyasa, with a suggestion as to the origin of Central African lakes. Map. *Geogr. Journ.*, Vol. 5, 1895, pp. 112–124.

KNOX, ALEXANDER. The climate of the continent of Africa. 552 pp.; map, diagrs. Cambridge, 1911.

KOETTLITZ, REGINALD. A journey through Somaliland and southern Abyssinia to the Shangalla or Berta country and the Blue Nile and through the Sudan to Egypt. Ills. *Journ. Manchester Geogr. Soc.*, Vol. 16, 1900, pp. 1–30.

KUMM, KARL. Von Haussaland nach Ägypten durch den Sudan. Vorläufiger Bericht über meine Afrikadurchquerung 1908–1909. Map. *Petermanns Mitt.*, Vol. 56, 1910, p. 56.

KUSS, M. *See* MARC.

LABONNE, LE LIEUTENANT. Le pays Trarza. Map. *La Géographie*. Vol. 19, 1909, pp. 290–294.

LEFEBVRE, C. T. Voyage en Abyssinie exécuté pendant les années 1839, 1840, 1841, 1842, 1843. 6 vols.; plates. Paris, [1845].

LEGAT, C. E. Report of the conservator of forests. *Ann. Rept. Transvaal Dept. of Agric., 1903–1904*, pp. 321–335. Pretoria, 1905.

LENFANT, E. A. Le Niger: Voie ouverte à notre empire africain. 255 pp.; maps, ills., plates. Paris, 1903.

LENZ, OSCAR (1881). Voyage du Maroc au Sénégal. Map. *Bull. Soc. de Géogr. de Paris*, Ser. 7, Vol. 1, 1881, pp. 199–226.

LENZ, OSCAR (1884). Timbuktu: Reise durch Marokko, die Sahara, und den Sudan ausgeführt im Auftrage der Afrikanischen Gesellschaft in Deutschland in den Jahren 1879 und 1880. 2 vols.; maps, plates. Leipzig, 1884.

LÉONTIEFF, COMTE N. DE. Exploration des provinces équatoriales d'Abyssinie. Map, ills. *La Géographie*, Vol. 2, 1900, pp. 105–118.

LEPLAE, EDMOND (1914). Agriculture in the Belgian Congo. *Bull. Imperial Inst.*, Vol. 12, 1914, pp. 60–75. London.

LEPLAE, EDMOND (1921). Exploitation d'une ferme au Katanga et dans les régions élevées du Congo belge. Map, ills. *Bull. Agric. Congo Belge*, Vol. 12, 1921, pp. 3–211.

LEVERSON, J. J. Geographical results of the Anglo-Portuguese delimitation commission in South-east Africa, 1892. Map, ills. *Geogr. Journ.*, Vol. 2, 1893, pp. 505–518.

LIVINGSTONE, DAVID (1858). Missionary travels and researches in South Africa, including a sketch of sixteen years' residence in the interior of Africa, and a journey from the Cape of Good Hope to Loanda on the west coast, thence across the continent, down the River Zambesi, to the eastern ocean. 755 pp.; maps, plates. New York, 1858.

LIVINGSTONE, DAVID and CHARLES (1865). Narrative of an expedition to the Zambesi and its tributaries, and of the discovery of the lakes Shirwa and Nyassa, 1858–1860. 608 pp.; map, ills., plates. London, 1865.

LIVINGSTONE, DAVID (1874). Letters. *Proc. Royal Geogr. Soc.*, Vol. 18, 1874, pp. 255–281.

[LIVINGSTONE, DAVID] (1874a). The last journals of David Livingstone, in Central Africa, from 1865 to his death. Continued by a narrative of his last moments and sufferings, obtained from his faithful servants Chuma and Susi. By Horace Waller. 2 vols.; maps, ills., plates. London, 1874.

LLOYD, WATKISS. Notes on Kordofan Province. Maps, ills. *Geogr. Journ.*, Vol. 35, 1910, pp. 249–267.

LUGARD, E. J. The flora of Ngamiland. Map. *Royal Botanic Gardens, Kew, Bull. of Misc. Inform.*, 1909, pp. 81–89.

LUGARD, F. D. A journey in West Africa, and some points of contrast with East Africa. *Scottish Geogr. Mag.*, Vol. 11, 1895, pp. 609–625.

MACDONALD, J. R. L., and H. H. AUSTIN. Journeys to the north of Uganda. Map, ills. *Geogr. Journ.*, Vol. 14, 1899, pp. 129–155.

MACHAT, J. Essai sur la géographie du Fouta-Diallon. Map. *Renseign. Colon.* (*Suppl. à l'Afrique Française*), 1900, pp. 124–145. Paris.

MACKINDER, H. J. A journey to the summit of Mount Kenya, British East Africa. Map, ills., plates. *Geogr. Journ.*, Vol. 15, pp. 453–486.

MCLEOD, LYONS. Travels in eastern Africa, with the narrative of a residence in Mozambique. 2 vols.; map, plates. London, 1860.

MCLEOD, N. C. Statement by Mr. N. C. McLeod, Conservator of Forests, Gold Coast Colony, for the British Empire Forestry Conference, London, 1920, 18 pp.; map.

MAISTRE, CASIMIR (1893). La Mission Maistre (Du Congo au Niger à travers l'Afrique centrale). Map, ills. *Le Tour du Monde*, Vol. 66, 1893, pp. 305–368.

MAISTRE, CASIMIR (1893a). M. Casimir Maistre's Journey from the Congo to the Shari and Benue. *Geogr. Journ.*, Vol. 2; 1893, pp. 323–325. [Transl. from *Comptes Rendus* of the Paris Geographical Society, 1893.]

MANETTI, CARLO. Le sparto nell'Africa settentrionale. Ills., plates. *Agric. Colon.*, Vol. 8 (2), 1914, pp. 553–576, 641–663, 743–763, 815–839. [Also reprinted, Florence, 1915.]

MARC, M., and M. KUSS. Notes sur les forêts de l'Algérie. 331 pp.; maps, graphs. Algiers, 1916.

MARÈS, ROGER. *See* TRABUT, LOUIS, and ROGER MARÈS.

MARLOTH, RUDOLF (1887). Das südöstliche Kalahari-Gebiet. *Botanische Jahrbücher*, Vol. 8, 1887, pp. 247–260.

MARLOTH, RUDOLF (1905). The phyto-geographical subdivisions of South Africa. Map, plates. *Rept. British Assn. for the Advancement of Science No. 75*, 1905, pp. 589–590.

MARLOTH, RUDOLF (1908). Das Kapland, insonderheit das Reich der Kapflora, das Waldgebiet und die Karroo, pflanzengeographisch dargestellt. Mit Einfügung hinterlassener Schriften A. F. W. Schimpers. 436 pp.; maps, ills., plates. (Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898–1899, Vol. 2, Part 3.) Jena, 1908.

MARLOTH, RUDOLF (1910). The vegetation of the southern Namib. Plates. *Rept. South African Assn. for the Advancement of Science No. 7*, 1909, pp. 80–87. 1910.

MASSART, JEAN. Un voyage botanique au Sahara. Plates. *Bull. Soc. Royale de Botanique de Belgique*, Vol. 37, 1898, pp. 202–339.

MATHUISIEULX, H. M. DE. À travers la Tripolitaine. 221 pp.; maps, ills., plates. Paris, 1903.

MAUGHAM, R. C. F. Portuguese East Africa: The history, scenery, and great game of Manica and Sofala. 340 pp.; map, plates. London, 1906.

MAURETTE, FERNAND. État de nos connaissances sur le nord-est africain. Maps. *Ann. de Géogr.*, Vol. 14, 1905, pp. 339–364, 433–455.

MEYER, HANS (1900). Der Kilimandjaro: Reisen und Studien. 436 pp.; map, ills., plates. Berlin, 1900.

MEYER, HANS, edit. (1909–10). Das Deutsche Kolonialreich: Eine Länderkunde der deutschen Schutzgebiete. Unter Mitarbeit von Siegfried Passarge, Leonhard Schultze, Wilhelm Sievers und Georg Wegener. 2 vols.; maps, plates. Leipzig and Vienna, 1909–10.

MEYER, HANS (1909–10a). Ostafrika. Maps, diagrs., ills. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 1, pp. 1–416.

MEYER, HANS (1913). Ergebnisse einer Reise durch das Zwischenseengebiet Ostafrikas 1911. 127 pp.; map, plates. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 6.* Berlin, 1913.

MICHEL, CHARLES (1900). Mission De Bonchamps: Vers Fachoda à la rencontre de la Mission Marchand à travers l'Ethiopie. 560 pp.; map, ills., plates. Paris, [1900].

MICHEL, CHARLES (1900a). Résultats géographiques de la Mission De Bonchamps. Map, ills. *La Géographie*, Vol. 2, 1900, pp. 25–34.

[MILDBRAED, JOHANNES] (1908). Berichte des Botanikers Dr. J. Mildbraed [Expedition S. H. des Herzogs Adolf Friedrich zu Mecklenburg]. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 21, 1908, pp. 154–156.

MILDBRAED, JOHANNES (1914). Die Vegetationsverhältnisse im Sammelgebiet der Expedition. *In* Wissenschaftliche Ergebnisse der Deutschen Zentral-Afrika-Expedition 1907–1908 unter Führung Adolf Friedrichs, Herzogs zu Mecklenburg, Vol. 2, pp. 603–691. Leipzig, 1914.

MOLEMA, S. M. The Bantu, past and present: An ethnographical and historical study of the native races of South Africa. 398 pp.; map. Edinburgh, 1920.

MOLONEY, ALFRED. Sketch of the forestry of West Africa, with particular reference to its present principal commercial products. 533 pp. London, 1887.

MOLONEY, J. A. The Stairs expedition to Katangaland. *Geogr. Journ.*, Vol. 2, 1893, pp. 238–248.

MONTANDON, GEORGE. Au pays Ghimirra: Récit de mon voyage à travers le massif éthiopien (1909–1911). Maps, diagrs., ills. *Bull. Soc. Neuchâteloise de Géogr.*, Vol. 22, 1913, pp. 1–424.

MONTEIL, P. L. De Saint-Louis à Tripoli par le lac Tchad: Voyage au travers du Soudan et du Sahara accompli pendant les années 1890–91–92. 459 pp.; ills., plates. Paris. [1895.]

MOSELEY, L. H. Regions of the Benue. Map. *Geogr. Journ.*, Vol. 14, 1899, pp. 630–637.

MURIEL, C. E. Report on the forests of the Sudan. 2nd edit. 24 and 11 pp. Cairo, 1901.

NACHTIGAL, GUSTAV. Sahara und Sudan: Ergebnisse sechsjähriger Reisen in Afrika. 2 vols.; maps, ills., plates. Berlin, 1879–81.

NEAVE, S. A. (1906–07). A journey to north-east Rhodesia during 1904 and 1905. Map. *Memoirs and Proc. Manchester Literary and Philos. Soc.*, Vol. 51, 1906–07, Part II, No. 3, pp. 1–7.

NEAVE, S. A. (1910). A naturalist's travels on the Congo-Zambezi watershed. Map, plates. *Geogr. Journ.*, Vol. 35, 1910, pp. 132–146.

NEUMANN, OSCAR. From the Somali coast through southern Ethiopia to the Sudan. Map, ills. *Geogr. Journ.*, Vol. 20, 1902, pp. 373–401.

NEWLAND, H. O. Sierra Leone, its people, products, and secret societies: A journey by canoe, rail, and hammock, through a land of kernels, coconuts, and cacao, with instructions for planting and development. 251 pp.; plates. London, 1916.

NIEGER, J. Résultats scientifiques d'ensemble de la Mission du Transafricain. Map, ills. *La Géographie*, Vol. 29, 1914, pp. 73–109.

NOBBS, E. A. Agricultural problems at the Cape of Good Hope. *In* Science in South Africa: A handbook and review, edit. by W. Flint and J. D. F. Gilchrist, pp. 375–390. Cape Town, 1905.

NUGENT, W. V. The geographical results of the Nigeria-Kamerun boundary demarcation commission of 1912–1913. Map, plates. *Geogr. Journ.*, Vol. 43, 1914, pp. 630–649.

NURSE, C. G. A Journey through part of Somali-land, between Zeila and Bulhar. Map. *Proc. Royal Geogr. Soc.*, Vol. 13 (N. S.), 1891, pp. 657–663.

OLLONE, H. M. G. VICOMTE D' (1900). La jonction de la Côte d'Ivoire et du Soudan: La mission Hostains-d'Ollone. Map, ills. *Bull. Comité de l'Afrique Française*, Vol. 10, 1900, pp. 166–168.

OLLONE, H. M. G. VICOMTE D' (1901). Mission Hostains-d'Ollone 1898–1900: De la Côte d'Ivoire au Soudan et à la Guinée. 314 pp.; maps. Paris, 1901.

ORR, C. W. J. The making of Northern Nigeria. 306 pp.; maps. London, 1911.

PANET, LÉOPOLD. Relation d'un voyage du Sénégal à Soueira (Mogador). Map. *Rev. Coloniale*, Ser. 2, Vol. 5, 1850, pp. 379–445, 473–563.

PAOLI, GUIDO. Studi entomologici e botanici. Ills., plates. *Relaz. e Monogr. Agric.-Colon. Ist. Agric. Colon. Ital. 7* (Ricerche . . . fatte nella Somalia italiana meridionale, 1913), 1916, pp. 125–168.

PASSARGE, SIEGFRIED (1904). Die Kalahari: Versuch einer physisch-geographischen Darstellung der Sandfelder des südafrikanischen Beckens. 822 pp.; maps, ills. and portfolio of maps. Berlin, 1904.

PASSARGE, SIEGFRIED (1909–10). Kamerun. Maps, diagrs., ills. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 1, pp. 419–650.

PASSARGE, SIEGFRIED (1909–1910a). Togo. Maps, diagrs., ills. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 2, pp. 1–127.

PAULITSCHKE, PHILIPP. Die Sudânländer nach dem gegenwärtigen Stande der Kenntnis. 311 pp.; map, ills., plates. Freiburg, 1885.

PEARSON, A. N. The sugar industry of Natal. Ills. *In* Science in South Africa: A handbook and review, edit. by W. Flint and J. D. F. Gilchrist, pp. 423–438. Cape Town, 1905.

PEARSON, H. H. W. (1907). Some notes on a journey from Walfish Bay to Windhuk. Map, plates. *Royal Botanic Gardens, Kew, Bull. of Misc. Inform.*, 1907, pp. 339–360.

PEARSON, H. H. W. (1909). Percy Sladen memorial expedition in South-west Africa, 1908–1909. Maps, ills. *Nature*, Vol. 81, 1909, pp. 466–467, 499–500.

PEARSON, H. H. W. (1910). The travels of a botanist in South-west Africa. (Percy Sladen memorial expedition, 1908–1909, Report No. 1.) Map, plates. *Geogr. Journ.*, Vol. 35, 1910, pp. 481–513.

PEARSON, H. H. W. (1911). Through Little Namaqualand with the vasculum and the camera. Ills. *The Gardeners' Chronicle*, Ser. 3, Vol. 50, 1911, pp. 61–62, 124–125, 166–167, 190–191, 200–201.

PECHUËL-LOESCHE, EDUARD. *See* GÜSSFELDT.

PEEL, C. V. A. Somaliland: Being an account of two expeditions into the far interior, together with a complete list of every animal and bird known to inhabit that country, and a list of the reptiles collected by the author. 345 pp.; map, ills., plates. London, 1900.

PEGLER, ALICE. On the flora of Kentani. *Annals Bolus Herbarium* (South African College), Vol. 2, 1916, pp. 1–14, 112–128, 163–184.

PETERMANN, AUGUST, comp. An account of the progress of the expedition to Central Africa, performed by order of Her Majesty's Foreign Office, under Messrs. Richardson, Barth, Overweg and Vogel in the years 1850, 1851, 1852, and 1853. 14 pp.; maps. London, 1854.

PETERS, CARL. The Eldorado of the ancients. 447 pp.; maps, ills. London, 1902.

PFEIL, JOACHIM, COUNT. South-west Africa, English and German. Map, ills. *Geogr. Journ.*, Vol. 2, 1893, pp. 29–43.

PHILLIPS, E. P. (1917). A contribution to the flora of the Leribe plateau and environs, with a discussion on the relationship of the floras of Basutoland, the Kalahari, and the southeastern regions. Maps, ills. *Annals South African Museum*, Vol. 16, 1917, pp. 1–379.

PHILLIPS, E. P. (1920). A preliminary report on the veld-burning experiments at Groenkloof, Pretoria. Plates. *South African Journ. of Sci.*, Vol. 16, 1919–20, pp. 285–298.

PITARD, J., and L. PROUST. Les Iles Canaries, flore de l'archipel. Paris, 1908.

PLAT, J. Missions dans le Fouta-Djalon: Mission dite du Fouta-Djalon. Maps. *Bull. Soc. de Géogr. Commerc. de Bordeaux*, Ser. 2, Vol. 13, 1890, pp. 186–200, 201–223, 233, 252, 265–296, 297–312.

PLESSIS. *See* DU PLESSIS.

PLOWDEN, W. C. Travels in Abyssinia and the Galla country, with an account of a mission to Ras Ali in 1848. 485 pp.; maps. London, 1868.

POGGE, PAUL (1880). Im Reiche des Muata Jamwo: Tagebuch meiner im Auftrage der Deutschen Gesellschaft zur Erforschung Aequatorial-Afrikas in die Lunda-Staaten unternommenen Reise. 246 pp.; map, ills., plates. (Beiträge zur Entdeckungsgeschichte Afrikas, No. 3.) Berlin, 1880.

POGGE, PAUL (1881–82). Die Pogge-Wissmann'sche Expedition. *Mitt. Afrikanischen Gesell. in Deutschland*, Vol. 3, 1881–82, pp. 68–80, 146–154, 216–223, 248–254.

POLE EVANS, I. B. *See* EVANS.

PONCET, C. J. A voyage to Aethiopia made in the years 1698, 1699, and 1700. Describing particularly that famous empire; as also the kingdoms of Dongola, Sennar, part of Egypt, etc., with the natural history of those parts. 138 pp. London, 1709. [Transl. from the French.]

PRINGLE, J. W. With the railway survey to Victoria Nyanza. Map, ills. *Geogr. Journ.*, Vol. 2, 1893, pp. 112–139.

PROUST, L. *See* PITARD.

PURVIS, J. M. Forestry in Nyasaland. Statement prepared for the British Empire Forestry Conference, London, 1920. 10 pp.

QUINTIN, L. Souvenirs d'un voyage du Sénégal au Niger (1863–1866). *Bull. Soc. de Géogr. de Paris*, Ser. 7, Vol. 1, 1881, pp. 514–551.

RAPHAEL, J. R. Through unknown Nigeria. 361 pp.; plates. London, [1914?].

RATZEL, FRIEDRICH. The history of mankind. Transl. from the 2nd German edit. by A. J. Butler. 3 vols.; maps, ills., plates. London and New York, 1896–1898.

RAVENSTEIN, E. G. Messrs. Jackson and Gedge's journey to Uganda via Masai-land. Map. *Proc. Royal Geogr. Soc.*, Vol. 13 (N.S.), 1891, pp. 193–208.

RECLUS, ELISÉE. Nouvelle géographie universelle: La terre et les hommes. 19 vols. Paris, 1876–94. Africa discussed in Vols. 10–13, Paris, 1885–88. Engl. transl. by E. G. Ravenstein and A. H. Keane, 19 vols., London, 1878–94; Africa in Vols. 10–13.

RENDLE, A. B. (1911). A contribution to our knowledge of the flora of Gazaland: Being an account of collections made by C. F. M. Swynnerton. Map, plates. *Journ. Linnean Soc. of London*, Botany, Vol. 40, 1911, pp. 1–245.

RENDLE, A. B. (1913). Catalogue of the plants collected by Mr. and Mrs. P. A. Talbot in the Oban district, South Nigeria. 157 pp.; plates. London, 1913.

RIKLI, M., C. SCHRÖTER, and A. G. TANSLEY. Vom Mittelmeer zum Sahara-Atlas. [15] pp.; plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 10, No. 1–3, Section 2. Jena, 1912.

RITTER, KARL. Neu-Kamerun: Das von Frankreich an Deutschland im Abkommen vom 4. November 1911 abgetretene Gebiet beschrieben auf Grund der bisher vorliegenden Mitteilungen. 311 pp.; maps. (Veröffentlichungen des Reichskolonialamts, No. 4.) Jena, 1912.

ROHLFS, GERHARD. Ergebnisse meiner Reise nach Abessinien. Map. *Petermanns Mitt.*, Vol. 28, 1882, pp. 401–405.

ROOSEVELT, THEODORE, and EDMUND HELLER. Life-histories of African game animals. 2 vols.; maps, plates. New York, 1914.

SALESSE, CAPITAINE. De Conakry au Niger. *Bull. Union Géogr. du Nord de la France*, Vol. 18, 1897, pp. 43–67.

SALT, HENRY. A Voyage to Abyssinia, and travels into the interior of that country, executed under the orders of the British Government, in the years 1809 and 1810, etc. 506 and lxxv pp.; maps, ills., plates. London, 1814.

SANDERVAL, OLIVER DE. Soudan français: Kahel. 442 pp.; maps, ills. Paris, 1893.

SAROLEA, CHARLES. The economic expansion of the Congo Free State. Maps, ills. *Scottish Geogr. Mag.*, Vol. 21, 1905, pp. 182–197.

SCHENCK, ADOLF. Transvaal und Umgebungen. *Verhandl. Gesell. für Erdkunde zu Berlin*, Vol. 27, 1900, pp. 60–73.

SCHIMPER, A. F. W. Die indo-malayische Strandflora. 204 pp.; map, plates. *Botanische Mittheilungen aus den Tropen, No. 3.* Jena, 1891.

SCHIRMER, HENRI. Le Sahara. 443 pp.; maps, ills., plates. Paris, 1893.

SCHLECHTER, RUDOLF. Westafrikanische Kautschuk-Expedition 1899–1900. 326 pp.; ills., plates. Kolonial-Wirtschaftliches Komitee, Berlin, 1900.

SCHNEE, HEINRICH, edit. Deutsches Kolonial-Lexikon. 3 vols.; maps, ills., plates. Leipzig, 1920.

SCHOENFELD, E. D. Erythräa und der Ägyptische Sudan. 245 pp.; plates. Berlin, 1904.

SCHOENLAND, SELMAR (1919). Phanerogamic flora of the divisions of Uitenhage and Port Elizabeth. 118 pp.; map. *Union of South Africa, Botanical Survey, Memoir No. 1.* Pretoria, 1919.

SCHOENLAND, SELMAR (1920). A trip to the Knysna. *Royal Botanic Gardens, Kew, Bull. of Misc. Inform.*, pp. 227–231. London.

SCHRÖTER, CARL. *See under* FLAHAULT *and under* RIKLI.

SCHULTZE, A. Beobachtungen über die Fauna und Flora der Grashochländer Kameruns. *Naturwiss. Wochenschr.*, Vol. 8 (N.S.), 1909, pp. 513–514.

SCHULTZE, LEONHARD (1907). Aus Namaland und Kalahari: Bericht an die Kgl. Preuss. Akademie der Wissenschaften zu Berlin über eine Forschungsreise im westlichen und zentralen Südafrika, ausgeführt in den Jahren 1903–1905. 752 pp.; map, ills., plates. Jena, 1907.

SCHULTZE, LEONHARD (1909–10). Südwestafrika. Maps, diagrs., ills. *In* Hans Meyer, edit.: Das Deutsche Kolonialreich, Vol. 2, pp. 131–298.

SCHWEINFURTH, GEORG (1868). Pflanzengeographische Skizze des gesammten Nil-Gebiets und der Uferländer des Rothen Meeres. Map. *Petermanns Mitt.*, Vol. 14, 1868, pp. 113–129, 155–169, 244–248.

SCHWEINFURTH, GEORG (1869–71). Briefe. *Zeitschr. Gesell. für Erdkunde zu Berlin*, Vol. 4, 1869, pp. 311–333; Vol. 6, 1871, pp. 47–57.

SCHWEINFURTH, GEORG (1871). Reise nach den oberen Nil-ländern, IV: Reise in das Land der Niam Niam und Monbuttu, 1870. Map. *Petermanns Mitt.*, Vol. 17, 1871, pp. 11–16.

SCHWEINFURTH, GEORG (1894). Über seine letzte Reise mit Dr. Max. Schoeller in der italienischen Erythraea. *Verhandl. Gesell. für Erdkunde zu Berlin*, Vol. 21, 1894, pp. 379–431.

SCLATER, B. L. Routes and districts in southern Nyasaland. Map. *Geogr. Journ.*, Vol. 2, 1893, pp. 403–423.

SEEFRIED, ADOLF, BARON VON. Die Togo-Dahomey-Grenzvermessungs-Expedition, nebst Mitteilungen über Togo. Plates. *Mitt. Geogr. Gesell. in München*, Vol. 6, 1911, pp. 1–18.

SEINER, FRANZ (1909). Ergebnisse einer Bereisung des Gebiets zwischen Okawango und Sambesi (Caprivi-Zipfel) in den Jahren 1905 und 1906. Map, plates. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 22, 1909, pp. 1–111.

SEINER, FRANZ (1910). Trockensteppen der nördlichen und mittleren Kalahari. [14] pp., plates. *Vegetationsbilder, herausg. von G. Karsten und H. Schenck*, Ser. 8, No. 1. Jena, 1910.

SEINER, FRANZ (1912). Pflanzengeographische Beobachtungen in der Mittel-Kalahari. Plates. *Botanische Jahrbücher*, Vol. 46, 1912, pp. 1–50.

SEINER, FRANZ (1913). Ergebnisse einer Bereisung der Omaheke in den Jahren 1910–1912. Maps, plates. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 26, 1913, pp. 225–316.

SERPA PINTO, ALEXANDRE DE. How I crossed Africa from the Atlantic to the Indian Ocean, through unknown countries; discovery of the great Zambesi affluents, etc. Transl. from the author's manuscript by Alfred Elwes. 2 vols.; maps, ills., plates. Philadelphia, 1881.

SHANTZ, H. L. Urundi, territory and people. Maps, ills. *Geogr. Rev.*, Vol. 12, 1922, pp. 329–357.

SIEVERS, WILHELM. *See* HAHN.

SIM, JAMES. Extracts from a report on forestry in Southern Rhodesia. 44 pp.; plates. *Bull. Rhodesia Dept. of Agric. No. 71.*

SIM, T. R. (1909). Forest flora and forest resources of Portuguese East Africa. 166 pp.; 100 plates. . . . Aberdeen, Scotland, 1909.

SIM, T. R. (1910). The flora of Portuguese East Africa. *Rept. South African Assn. for the Advancement of Science*, No. 7, 1909, pp. 294–301. 1910.

SMITH, A. DONALDSON (1896). Expedition through Somaliland to Lake Rudolf. Map, ills. *Geogr. Journ.*, Vol. 8, 1896, pp. 120–137, 221–239.

SMITH, A. DONALDSON (1900). An expedition between Lake Rudolf and the Nile. Ills. *Geogr. Journ.*, Vol. 16, 1900, pp. 600–625.

SMITH, C. S. The Anglo-German boundary in east equatorial Africa: Proceedings of the British Commission, 1892. Map. *Geogr. Journ.*, Vol. 4, 1894, pp. 424–437.

SOLEILLET, PAUL. Voyages en Éthiopie (janvier 1882–octobre 1884). 347 pp. Rouen, 1886.

SPEKE, J. H. Journal of the discovery of the source of the Nile. 590 pp.; map, ills., plates. New York, 1864.

SPRIGADE, PAUL. Die französische Kolonie Dahome. Map. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 31, 1918, pp. 145–196.

STERN, H. A. Wanderings among the Falashas in Abyssinia, together with a description of the country and its various inhabitants. 322 pp. map, ills., plates. London, 1862.

STEVENSON-HAMILTON, J. Notes on a journey through Portuguese East Africa, from Ibo to Lake Nyasa. Map, ills. *Geogr. Journ.*, Vol. 34, 1909, pp. 514–529.

STIGAND, C. H. To Abyssinia through an unknown land: An account of a journey through unexplored regions of British East Africa by Lake Rudolf to the kingdom of Menelek. 352 pp.; maps, plates. London, 1910.

STUHLMANN, FRANZ (1894). Mit Emin Pascha ins Herz von Afrika: Ein Reisebericht mit Beiträgen von Dr. Emin Pascha, in seinem Auftrage geschildert. 901 pp.; maps, ills., plates. Berlin, 1894.

STUHLMANN, FRANZ (1895). Botanische Notizen über die in der Zeit vom 23. September bis 17. December 1894 unternommene Reise nach Uluguru. *Botanische Jahrbücher*, Vol. 21, 1895, pp. 194–206.

STUHLMANN, FRANZ (1895a). Über die Uluguruberge in Deutsch-Ostafrika. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 8, 1895, pp. 209–226.

STUHLMANN, FRANZ (1909). Beiträge zur Kulturgeschichte von Ostafrika: Allgemeine Betrachtungen und Studien über die Einführung und wirtschaftliche Bedeutung der Nutzpflanzen und Haustiere, mit besonderer Berücksichtigung von Deutsch-Ostafrika. 907 pp.; maps, ills. (Deutsch-Ost-Afrika, Vol. 10.) Berlin, 1909.

SWAYNE, H. G. C. Seventeen trips through Somaliland and a visit to Abyssinia: A record of exploration and big game shooting, 1885 to 1893, etc. 386 pp.; maps, ills., plates. London, 1895.

SWYNNERTON, C. F. M. Some factors in the replacement of the ancient East African forest by wooded pasture land. *South African Journ. of Sci.*, Vol. 14, 1918, pp. 493–518. Cape Town.

TAMISIER, MAURICE. *See* COMBES.

TANSLEY, A. G. *See* RIKLI.

THIELE, E. O., and R. C. WILSON. Portuguese East Africa between the Zambezi River and the Sabi River: A consideration of the relation of its tectonic and physiographic features. Maps, diagrs., plates. *Geogr. Journ.*, Vol. 45, 1915, pp. 16–45.

THODE, JUSTUS (1890). Die Küstenvegetation von Britisch-Kaffrarien und ihr Verhältnis zu den Nachbarfloren. *Botanische Jahrbücher*, Vol. 12, 1890, pp. 589–607.

THODE, JUSTUS (1894). Die botanischen Höhenregionen Natals: Ein Beitrag zur pflanzengeographischen Kenntnis des aussertropischen Südostafrika. *Botanische Jahrbücher*, Vol. 18, 1894, Beiblatt 43, pp. 14–45.

THOMAS, H. H. Some observations on plants in the Libyan Desert. Plate. *Journ. of Ecology*, Vol. 9, 1921, pp. 75–89.

THOMPSON, H. N. (1910). Gold Coast: Report on forests. 238 pp.; map, plates. *Misc. Colonial Repts. No. 66*. Cd. 4993. H. M. Stationery Office, London, 1910.

THOMPSON, H. N. (1910a). The topography, climate, and vegetation of the Gold Coast. Map. *Scottish Geogr. Mag.*, Vol. 26, 1910, pp. 466–478.

THOMPSON, H. N. (1920). Statements prepared by the Nigerian forest authority for the British Empire Forestry Conference, London, 1920. 25 pp.

THOMSON, JOSEPH. To Lake Bangweolo and the unexplored region of British Central Africa. Maps. *Geogr. Journ.*, Vol. 1, 1893, pp. 97–121.

THONNER, FRANZ (1899). Dans la grande forêt de l'Afrique centrale: Mon voyage au Congo et à la Mongala en 1896. 115 pp.; maps, ills., plates. Brussels, 1899.

THONNER, FRANZ (1910). Du Congo à l'Ubangi: Mon deuxième voyage dans l'Afrique centrale. 125 pp.; maps, ills., plates. Brussels and Paris, 1910.

THORNHILL, J. B. Adventures in Africa under the British, Belgian, and Portuguese flags. 330 pp.; map, diagrs. New York, 1915.

TILHO, JEAN (1906). Exploration du lac Tchad (février-mai 1904). Maps, diagrs., ills. *La Géographie*, Vol. 13, 1906, pp. 195–214.

TILHO, JEAN (1910). Le Tchad et les pays-bas du Tchad. Map. *La Géographie*, Vol. 21, 1910, pp. 149–168.

TILHO, JEAN (1910–14). Documents scientifiques de la Mission Tilho (1906–1909). 3 vols.; maps, ills., plates. Paris, 1910–19.

TILHO, JEAN (1916–17). Exploration du Commandant Tilho en Afrique centrale: Borkou, Ennedi, Tibesti, Dar-Four, 1912–1917. *La Géographie*, Vol. 31, 1917–17, pp. 401–417.

TILHO, JEAN (1920). The exploration of Tibesti, Erdi, Borkou, and Ennedi in 1912–1917: A mission entrusted to the author by the French Institute. Map, plates. *Geogr. Journ.*, Vol. 56, 1920, pp. 81–99, 161–183, 241–267.

TORDAY, E. Land and peoples of the Kasai basin. Map, plates. *Geogr. Journ.*, Vol. 36, 1910, pp. 26–57.

TRABUT, LOUIS (1888). Les zones botaniques de l'Algérie. *Assoc. Franç. pour l'Avanc. des Sci., Compte Rendu de la 17me Session, Oran, 1888*, Part II, pp. 286–294.

TRABUT, LOUIS (1889). Étude sur l'halfa (*Stipa tenacissima*). . . . 90 pp.; plates. Algiers, 1889.

TRABUT, LOUIS (1892). Herborisation dans le massif de l'Aurès les 10, 11, 12, 13, 14 juillet. *Bul Soc. Bot. de France*, Vol. 39, 1892, pp. 339–346.

TRABUT, LOUIS, and ROGER MARÈS. L'Algérie agricole en 1906. 531 pp.; ills., plates. Algiers, 1906.

TREVOR, T. G. The physical features of the Transvaal. Maps, ills. *Geogr. Journ.*, Vol. 28, 1906, pp. 50–65.

TROTHA, HELMUTH VON. Begleitworte zu der Garnison-Umgebungs-Karte von Massoko 1: 100,000. Map. *Mitt. aus den Deutschen Schutzgebieten*, Vol. 26, 1913, pp. 344–350.

UNION OF SOUTH AFRICA (PRETORIA). Statement relating to the Union of South Africa (Pretoria) prepared for the British Empire Forestry Conference, London, 1920.

UNWIN, A. H. (1909). Report on the forests and forestry problems in Sierra Leone. 54 pp.; plates. London, 1909.

UNWIN, A. H. (1920). West African forests and forestry. 527 pp.; plates. London, 1920.

VAGELER, PAUL. Die Mkattaebene: Beiträge zur Kenntnis der ostafrikanischen Alluvialböden und ihrer Vegetation. Diagrs., plates. *Tropenpflanzer Beiheft No. 11*, 1910, pp. 251–395.

VAHL, M. Über die Vegetation Madeiras. *Botanische Jahrbücher*, Vol. 36, 1905, pp. 253–349.

VANDELEUR, C. F. S. Two years' travel in Uganda, Unyoro, and on the upper Nile. Map, ills. *Geogr. Journ.*, Vol. 9, 1897, pp. 369–393.

VAN DER BURGT. *See* BURGT.

VASSE, GUILLAUME (1907). Recent developments in Portuguese East Africa. *Bull. Imperial Inst.*, Vol. 5, 1907, pp. 55–64. London.

VASSE, GUILLAUME (1909). Trois années en mission dans le Mozambique. *La Géographie*, Vol. 19, 1909, pp. 191–206.

VISCHER, HANNS. De Tripoli au lac Tchad. *La Géographie*, Vol. 20, 1909, pp. 349–356.

VOLKENS, GEORG (1887). Die Flora der ägyptisch-arabischen Wüste auf Grundlage anatomisch-physiologischer Forschungen. 156 pp.; plates. Berlin, 1887.

VOLKENS, GEORG (1897). Der Kilimandscharo: Darstellung der allgemeineren Ergebnisse eines fünfzehnmonatigen Aufenthalts im Dschaggalande. 388 pp.; map, ills., plates. Berlin, 1897.

WALLACE, L. A. North-eastern Rhodesia. Map, ills. *Geogr. Journ.*, Vol. 29, 1907, pp. 370–400.

WALLACE, ROBERT. Farming industries of Cape Colony. 552 pp.; maps, diagrs., ills., plates. London, 1896.

WEISS, F. E. (1905). Some aspects of the vegetation of South Africa. Part I: The flora of the Cape Peninsula. Ills., plate. *The New Phytologist*, Vol. 4, 1905, pp. 223–232. London.

WEISS, F. E. (1906). Some aspects of the vegetation of South Africa. Part II: Natal and the Transvaal. Ills., plates. *The New Phytologist*, Vol. 5, 1906, pp. 1–9.

WEISS, F. E., and R. H. YAPP. "The Karroo" in August. Ills., plates. *The New Phytologist*, Vol. 5, 1906, pp. 101–115.

WELLBY, M. S. (1900). King Menelek's dominions and the country between Lake Gallop (Rudolf) and the Nile valley. Map. *Geogr. Journ.*, Vol. 16, 1900, pp. 292–306.

WELLBY, M. S. (1901). 'Twixt Sirdar and Menelik: An account of a year's expedition from Zeila to Cairo through unknown Abyssinia. 409 pp.; maps, ills. London and New York, 1901.

WEULE, KARL. Wissenschaftliche Ergebnisse meiner ethnographischen Forschungsreise in dem Südosten Deutsch-Ostafrikas. 150 pp.; map, plates. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 1*, Berlin, 1908.

WHITLOCK, G. F. A. The Yola-Cross River boundary commission, Southern Nigeria. Map, plates. *Geogr. Journ.*, Vol. 36, 1910, pp. 426–438.

WICKENBURG, EDUARD, COUNT VON. Wanderungen in Ost-Afrika. 440 pp.; maps, ills., plates. Vienna, 1899.

WILDEMAN, ÉMILE DE (1908). Coup d'œil sur la distribution des végétaux dans l'Afrique tropicale. Maps, ills. *In his* "Les plantes tropicales de grande culture," etc., Vol. 1, pp. 1–24. Brussels, 1902.

WILDEMAN, ÉMILE DE (1913). Documents pour l'étude de la géo-botanique congolaise. 406 pp.; maps, ills., plates. *Bull. Soc. Royale de Botanique de Belgique*, Vol. 51, fascicule 3. 1913.

WILKINSON, EDWARD. Notes on a portion of the Kalahari. Map. *Geogr. Journ.*, Vol. 1, 1893, pp. 324–339.

WILLCOCKS, SIR WILLIAM. The sudd reservoir, or nature's provision of perennial irrigation and flood protection of the whole of the Nile valley. *Bull. l'Inst. d'Égypte*, Vol. 1, 1918–19, pp. 35–69. Cairo.

WILSON, R. C. *See* THIELE.

WISE, C. D. Report on land settlement in Southern Rhodesia. 26 pp. London, 1906.

WISSMANN, HERMANN VON (1889). Unter deutscher Flagge quer durch Afrika von West nach Ost, von 1880 bis 1883 ausgeführt von Paul Pogge und Hermann Wissmann. 4th edit. 444 pp.; maps, plates. Berlin, 1889.

WISSMANN, HERMANN VON (1891). My second journey through equatorial Africa from the Congo to the Zambesi in the years 1886 and 1887. Transl. from the German by Minna J. A. Bergmann. 326 pp.; map, ills. London, 1891.

WOHLTMANN, FERDINAND. Der Plantagenbau in Kamerun und seine Zukunft. Drei Reiseberichte. . . . 39 pp.; map, plates. Berlin, 1896.

WOLFF, WILLY. Von Banana zum Kiamwo. 248 pp.; map. Oldenburg and Leipzig, 1889.

WOLLASTON, A. F. R. From Ruwenzori to the Congo: A naturalist's journey across Africa. 315 pp.; map, plates. London, 1908.

YAPP, R. H. *See* WEISS, F. E., and R. H. YAPP.

ZIMMERMANN, KARL, and others. Die Grenzgebiete Kameruns im Süden und Osten, hauptsächlich auf Grund der Ergebnisse der Grenzexpeditionen: Landeskundlicher Teil. 131 pp.; maps, plates. *Mitt. aus den Deutschen Schutzgebieten Ergänzungsheft No. 9a.* Berlin, 1914.

ZIMMERMANN, MAURICE. Résultats des missions Blondiaux et Eysséric. Map, plates. *Ann. de Géogr.*, Vol. 8, 1899, pp. 252–264.

PART II
THE SOILS OF AFRICA

CHAPTER V

THE PRINCIPLES OF SOIL SCIENCE

Soil science, in so far as it concerns the study of the character, distribution, and relationships of soils in their natural place, is one of the youngest of the sciences. Until the nineteenth century was more than half gone the prevailing opinion regarding the origin and nature of soils did not differentiate them from mere accumulations of unconsolidated earthy deposits with more or less admixture of organic matter. The study of such deposits had long been part of the recognized field of geological science.

The results obtained in the investigation of an object or series of objects depend as much or more on what is present in the mind of the investigator as on the nature of the object or group investigated. The point of view of the investigator, his limitations, and the particular information he is seeking are important factors. The investigator may deliberately limit the range of his studies or he may be limited in his range by the limitation of his knowledge. It probably never happens that an object is investigated in all possible directions by any one group of investigators or by the representatives of any one science.

The Study of Soils by Geologists and Agronomists

Concerning any deposit of unconsolidated material the geologist inquires as to its mineralogical constitution; the period, measured by his own chronological scale, when it was accumulated; and the process or processes by which the accumulation was effected. An important part of the soils of the world, however, can be traced back to material that was accumulated by the processes of rock disintegration and decomposition in place without removal and reaccumulation in other places by the processes of transportation and deposition. Geologists have given very

little attention to this method of accumulation of unconsolidated earthy materials in the concrete, though the processes in the abstract have received a great deal of attention and much good work has been done in treating them. Application of the principles thus developed to the study of particular cases of accumulation is rare. The geologist, therefore, did not concern himself with the processes by which all earthy materials are accumulated and has neglected to give more than passing attention to the materials that cover a large part of the earth's surface.

Even in the case of other unconsolidated deposits than those originating through the decay of the rocks in place the geologist stopped far short of the goal that must be reached in the study of the soil. The geological deposit, the glacial till, the sandy deposits of the sand plains, the lake-laid or marine clays, sands, silts, and gravels, the residual earth resulting from rock decay constitute *soil materials* or *parent materials of soils*. The geologist has concerned himself with the *accumulation of the soil material* and not with the *evolution of the soil from this material.*

This material does not long retain its original characteristics. Changes begin at once under the powerful influences of climatic forces and the forces and processes of organic life, vegetable and animal. For a brief period this material is both soil and soil material. As soon as any change, however minute, has been effected by the weather or by organic life it is no longer mere soil material, though the features characterizing it as parent material predominate then and long afterward.

Another group of men, previous to the seventies of the nineteenth century, interested itself in the soil. They, the agronomists, looked upon the soil not as a natural body developed by natural forces acting through natural processes but thought of it only as an instrument for crop production. Their efforts were directed not to a study of the soil as such and for the purpose of finding out the whole truth about it but to the determination of the reasons for its productivity or unproductivity and to the discovery of a means of making it more productive.

By neither group of investigators was the soil studied as such;

nor did they consider that such study would produce results of any economic importance or of any independent, comprehensive scientific value. Since soil characteristics were ascribed solely to the parent rock, there was no inducement to study the soil itself. Under such conditions a soil science could not develop, since no body of facts concerning an object or group of objects can exist without the examination of the objects.

The Development of Modern Soil Science

Modern science developed in western Europe and eastern North America. In these regions the soils, broadly speaking, are not only similar in general characteristics but are lacking in features that arrest man's attention. As long as the development of the earth sciences was confined to these regions the soil, mainly because of these characteristics, received little or no attention. The directing of special attention to the soil had to wait for the time when students of earth science extended the range of their observations into regions where soils were different from those in western Europe and had features that commanded attention.

There are two groups of soils in the world whose characteristics differ strikingly from those of western Europe as well as from each other. One of these groups is that of the laterites of the tropics and the other that of the *chernozems*, or black earths, of the great continental interiors.

STUDY OF LATERITE

In the early part of the nineteenth century, the geologists of India began to direct their attention to the great masses of red surface material found in many parts of that country. It was not until well toward the end of the century, however, that it was recognized as a soil, i. e. as a product of weathering in place and not as a deposit of detrital material brought from elsewhere and laid down with all its present characteristics in full development from the beginning. Although this body of material is a soil and was finally shown to be such, yet it did not become the

object of courses of investigation that created the new science of the soil. Its characteristics are striking, even those open to observation without the use of special appliances. It was recognized as unique from the geological point of view, yet it was subjected to no searching examination, chemical, physical, or geographic, in an attempt to explain its apparent uniqueness. Hundreds of pages of description of its characteristics and of discussion as to its origin and processes of development were printed, mainly in English, during the nineteenth century, beginning with Buchanan in 1807. His term for it, "laterite," from the Latin *later*, a brick, because of its extensive use, when cut into blocks, as a native building material, came to be its universally accepted designation. Even after it had been generally agreed that its characteristics had been impressed upon it by weathering, no one seems to have conceived of the possibility of determining, by geographic study, the relation of soils to any particular type of weathering or of building up a science of the relationship of varying processes of weathering to varying types of weathered products.

The first serious attempt to determine the chemical composition of laterite was made near the end of the nineteenth century, and the first recognition of the significance of its peculiar characteristics followed this, but not until an entirely different group of soils located in an entirely different region had aroused the interest and inspired the work which created the science of the soil. Yet laterite has a series of characteristics just as striking and a distribution just as significant as the other soil group and could have supplied the data for this discovery equally well.

STUDY OF CHERNOZEM

The other of the two groups of soils referred to above, the chernozem, or black earth, of south-central Russia and west-central Siberia, probably presents more striking characteristics than any large body of soil encountered by scientific men before the middle of the nineteenth century. Such dark-colored soils as occur in western Europe are confined to small areas where exces-

sive moisture conditions exist, the land being available for ordinary agricultural use only when drained by artificial means. The discovery of great areas of black soil in a region not only well drained but characterized by a deficiency rather than by an excess of moisture was a source of great surprise to the scientists familiar with the soils of western Europe. As early as 1763 a paper was published on this soil, and from that time up to the latter part of the nineteenth century it was the object of a great and increasing amount of attention. Many papers were published describing its characteristics and discussing its origin. With few exceptions the writers of these papers either assumed or undertook to prove this soil to be a geological formation, its striking characteristics being ascribed either to the character of the material deposited or to the conditions of deposition.

Not until the problem had been attacked from an entirely different standpoint, first by Rupprecht and later and finally by Dokuchayev, was it finally solved. These investigators showed that the area covered by this soil was underlain, in its different parts, by many kinds of rocks and a great many geological formations and that, notwithstanding this great diversity in the sources of the parent material from which the soil had undoubtedly been derived, it retained throughout the area all its essential and fundamental characteristics. Through this fact it became evident that the fundamental characteristics of this soil could not be due to geological features and must be sought in other relationships. A study of the distribution throughout Russia of this soil and its correlation with the distribution of climatic and vegetational features gave the clue. It was finally shown conclusively that this soil is the product of climatic forces acting both directly and through the medium of the native vegetation.

ESTABLISHMENT OF FACT THAT SOILS ARE PRODUCT OF CLIMATIC FORCES

In the demonstration of this relationship lay the beginnings of a new science of the soil. The soil became more than a local phenomenon without characteristics of its own or a progressive

course of development. Through the opportunity offered to the Russian investigators by the unified political control of an immense area of country with a wide range of geologic, climatic, and topographic conditions they worked out many important laws of soil development and soil distribution and showed that these were intimately related to climatic and vegetational conditions. American workers have widened the field thus opened by showing the intimate relation of soil type character to topographic form and to stage in development.

Brief mention only can here be made of those results of modern soil science that have an important geographic significance.

Modern soil investigators, Russian and American, have shown the existence of a remarkable belted distribution of soils in the Eurasian and North American continents. Such studies as have been made in South America also suggest that the distribution there is of a similar type. The fact that this distribution, based upon a definition and identification of soil units in terms of their general characteristics as soils, is not local, is prima facie evidence that their general characteristics have been impressed upon them by forces having the same systematic and regular distribution over the surface of the continents as the soils themselves. The materials from which these soils are made are of geological derivation and partake of the characteristics of geological formations. But the distribution of geological formations over the surface of the continents is wholly devoid of any regularity or schematic arrangement. It is evident, therefore, that the forces producing such schematic regularity in the distribution of soil characteristics are stronger as determinants of soil character than is the parent soil material or any other influence, such as topographic conditions, whose distribution is not as regular as that of the soils.

The coincidence of soil belts and climatic belts has caused soil students to conclude that climatic forces are the predominant soil-forming agencies of the world, obliterating or reducing to a subordinate position in a relatively short time the influence of the parent rock material. In fact, in a study of the soils of a region, taking into consideration their broad, general characteristics

only, the influence of the parent material may be mainly neglected or entirely so. This may be done with less and less risk of error as the climatic forces become more and more powerful.

Classification of Soils

The soil groups established by Russian investigators

Studies by Russian soil scientists resulted in the establishment of seven great soil groups: the *tundra soils*, the *podsols*, the *gray forest soils*, the *chernozems*, the *chestnut-brown soils*, the *brown soils*, and the *gray desert soils*. To these main groups investigators elsewhere have added the *yellow soils*, the *prairie soils*, the *laterites*, and the *red loams*. Several important subdivisions of some the main Russian groups have been established also. Because of the distinctive colorings which are, to the casual observer, the most readily discerned differences between the various soil groups, the Russian scientists designated most of the soils studied by their characteristic color. For want of a better nomenclature this plan has been almost universally employed, and some of the Russian names—notably *chernozem*, or black soil, and *podsol*, or gray soil—are still retained. In the following discussion of these soil groups, which proceeds from north to south, the tundra soils are omitted, as they do not occur in Africa.

Podsols

The podsols, in Russia and Siberia, are light-colored, timbered soils lying north of the chernozems, covered, from an inch or two to nearly a foot, with forest débris and occupying a region of relatively low temperature and high rainfall. Because of a relatively high rainfall in the region where these soils develop, namely northern Europe, they are subjected to the influence of abundant percolating water. This prevents the accumulation of lime carbonate and removes in a relatively short time any of that material that may have been present originally in the parent rock, while the surface horizon is leached of iron, alumina, and, to some extent, of alkalies and alkaline earth bases and these are carried downward with dissolved organic matter. These latter

are precipitated a few inches below the surface, forming a coffee-brown horizon which is often indurated to a hardpan. A dense timber cover resulting in the complete shading of the ground, low temperature, and high rainfall favor the accumulation of a surface coating of forest débris which excludes the air and makes impossible the existence of fauna to assist in the disintegration of the organic matter and the mixing of the soil. Characteristic of podsols are the gray, leached surface horizon, reduced to a powdery structure totally devoid of granulation, and the brown horizon a few inches beneath the surface.

Gray Forest Soils

The gray forest soils develop under a rainfall of 25 inches to 40 inches in a temperature like that of the middle latitudes of Europe and the United States, under an open timber cover consisting, to an important extent, of oak, beech, elm, maple, and chestnut. Although they are timber-covered, their profile differs greatly from that of the podsols, especially in the absence of the characteristic gray or podsolized horizon of the latter and of the coffee-brown or hardpan horizon. They are covered with a layer of vegetable débris, the lower part of which is decomposed into a dark-colored mold in which the structure of the leaf and other parent materials has largely disappeared but which is not dense enough to prevent the existence of a fauna which assists in the disintegration of the organic matter and its incorporation with the soil. The upper inch or two, therefore, is dark rather than gray like the podsols and is succeeded downward by a brownish to yellowish brown horizon of about the same texture as the surface, then by a heavier brown horizon which extends to the partially changed parent rock at about three feet.

Chernozems

According to observations first made in Russia and Siberia and verified elsewhere, chernozem is limited to a rather narrow range of effective soil moisture supply, which is dependent, not on rainfall only, but also upon evaporation. Consequently,

although in general the soil is developed under a rainfall ranging from a little less than 16 to a little more than 20 inches, it is probable that in far northern latitudes it may develop under less than the minimum and in southern latitudes under considerably more than the maximum. In addition to this definite range of effective moisture supply, a grass cover that has persisted through a long period of time seems essential to the development of this soil. As far as observed no tree growth has occupied any chernozem area for a long time, if ever; in fact, where trees encroach along the edge of a belt, the soil rapidly loses its essential characteristics. Chernozems have two outstanding characteristics: (1) a black color and (2) a zone of lime carbonate concretions accumulated in the lower part of the soil section during the progress and through the action of the processes of the soil's development regardless of the composition of the parent rock, leaving out of consideration certain rocks of relatively limited distribution and extremely simple composition, like quartzite. They are equally independent of the processes by which the parent soil material was accumulated.

Chestnut-Brown Soils

The chestnut-brown soils, in Russia and Siberia, occupy a belt of country with a drier and warmer climate than that of the chernozem belt. They have a thin, dark-colored, slightly reddish or chocolate surface horizon containing a great abundance of grass roots. Their occurrence in other countries suggests that the warmer climate is of less importance in their development than the lower rainfall, the temperature appearing to operate mainly in decreasing the effectiveness of the rainfall through evaporation. Like the chernozems these soils are developed under a grass vegetation, but the scantier moisture supply affords a less heavy growth than in the chernozem belt. The dark-colored horizon is underlain usually by a brown horizon of the same texture and this in turn by a zone of carbonate accumulation which, because of the scantier moisture supply, is closer to the surface than in the chernozems and of a rather uniform concen-

tration instead of localization in spots or concretions, as is true of the latter.

Brown Soils

The brown soils lie still farther south in a region of still scantier rainfall. They are treeless, with a discontinuous cover of grass and a variety of shrubs. They are lighter in color than the chestnut-brown soils; and the zone of carbonate accumulation is still nearer the surface, its depth being only a foot or less.

Gray Desert Soils

The gray desert soils are developed in a still drier region, where the rainfall is less than 8 inches. The ground is bare as far as perennial grass is concerned, the vegetation being limited to a few perennial shrubs and bunches of annual plants that spring up rapidly after a rain, ripen, seed, and die. The surface soil is gray to very light brown with a varied profile beneath, though a zone of carbonate accumulation is always present in the mature soil.

SOIL GROUPS ESTABLISHED OUTSIDE OF RUSSIA

We turn now to the soil groups which have been established by scientists outside of Russia and Siberia.

Yellow Soils

The yellow soils, in the north temperate zone, develop in a region with a more moist and hotter climate than that of the gray forest soils, from which they differ in appearance to only a relatively slight extent. They are less heavily timbered than the gray forest soils, and the layer of débris is thinner and in many cases composed of débris from evergreens. The surface soil, including about 3 inches of dark surface material and from 6 to 12 inches of the subsurface soil, is lighter in texture than corresponding horizons in the gray forest soils, and, although the upper dark horizon is thicker, its organic matter seems less decomposed. The subsurface horizon is pale yellow, almost gray at times, and the heavier subsoil is yellow, modified in

places by various shades of color. Often the surface soil is a sand and the subsoil is sandy clay, owing partly to translocation by heavy rainfall of fine silt and clay particles from the surface to 12 to 15 inches beneath. The temperature under which these soils are developed is practically permanently above freezing point, so that the soil is subject to leaching throughout the twelve months of the year by heavier rain than any previously described group. The results are shown in the light texture of the surface as compared with the subsoil and, to an even more important extent, in the thorough decomposition of the soil and the more thorough removal of the alkalies, alkaline earths, and iron. These soils are highly eluviated and strongly leached.

Prairie Soils

Important in the north temperate zone in the western hemisphere but of slight occurrence in Eurasia are the black or dark brown prairie soils. These soils are developed under a grass cover within a rainfall range of 35 to 40 inches and are leached of parent rock carbonates, while none are permitted to accumulate. The surface soil is somewhat lighter in texture than the subsoil and is not covered by a horizon or layer of accumulated organic matter.

Laterites and Red Loams

Second only to the chernozems in the rôle which they have played in the development of soil science are the laterites and red loams developed in hot climates under a high rainfall. Common to these two groups of soils is the iron constituent, usually though not invariably present, which in other soil groups occurs in so small a quantity or in such form that its presence is not a dominant factor in any of the soil characteristics. Iron oxide is not an essential constituent of laterite; but, on account of the almost universal presence of iron in rocks and of the peculiar processes of laterite development, its occurrence in these soils is so widespread and its color so striking that the red color produced by it is regarded by many as a universal and essential characteristic of laterites. It is always present in red loams. The soils of

these groups are developed in the presence of too low a percentage of organic matter to reduce and carbonate the iron of the parent rock, while, on the other hand, the prevailing high temperature tends to oxidize it and the abundance of moisture tends to hydrate it. The high temperature, however, seems to prevent a high degree of hydration, so that the color is predominantly bright red. On the other hand, if iron is not present in the parent rock, the soil will also be free from it and the color will not be red.

Laterites

Laterites may be light in color or, in extreme cases, may be dark; but it is not probable that any member of the group is permanently dark-colored. More characteristic of laterite are the high percentage of alumina present as well as the form in which it occurs and the silica-alumina ratio. Unless alumina is present in the parent rock no member of the laterite group will be developed from it. In all soils, however, there is a higher percentage of alumina than is present in the parent rock, but in non-lateritic soils it occurs in a form entirely different from that of the laterites, being usually in the form of undecomposed mineral from the parent rock, mainly as aluminum silicates of the alkalies or alkaline earths, or in the form of aluminum silicate, a decomposition product. In the laterites it is always present in the form of aluminum hydroxide, mainly with a formula like that of gibbsite, with about 65 per cent of alumina and 35 per cent of water. In addition no aluminum silicates, or at least a low percentage, are present, the silica having been carried away in solution during the progress of laterite development. In some cases it seems that the silica has separated out in some of the forms of quartz or crystalline silica and remained in the soil. There is, therefore, in these soils an absence of combined silica, a condition entirely different from that of other soils. Developed under a very high rainfall—probably a minimum of 50 inches—laterites have been subjected to the processes of leaching to a much greater extent than any other soil group. Alkalies are practically exhausted, and, in all cases, the soil has apparently been subjected

to the processes of eluviation by the action of which the surface becomes relatively light in texture and the subsoil heavy. In cases where iron is present in considerable quantities in the parent rock, so much iron hydroxide accumulates in the soil that it segregates into crusts, concretions, and especially into skeleton-like masses in the subsoil, forming a material which is often indurated.

Red Loams

The red loams do not as yet stand on a par with the other soil groups. There is no universal agreement among soil students as to their right to a place among the great soil groups of the world. It is by no means certain that they do not represent phases or stages in the development of other soil groups and have no more claim to recognition as a great soil group than have caterpillars a right to recognition as an independent group of insects. The term is applied to a group of red soils, similar in color to laterites but differing from them in the presence of a high percentage of aluminum silicate as a constituent, rather than of aluminum hydroxide. Their silica is present in the form of combined silica as well as of quartz instead of as quartz alone. The accepted definition of the term does not exclude the presence of aluminum hydroxide; but the amount present, relatively to that of the silicate, is small. They are usually free from accumulations of iron oxide crusts or other forms of segregation, and the process of eluviation has not reached so advanced a stage as in the laterites. They have been developed from rocks with a considerable, but not necessarily very high, percentage of iron. They have a low percentage of organic matter, have developed under timber cover, and in warm to hot climates with high rainfall.

The term is often used to include a group of red soils, derived from limestone, known as *terra rossa*. The latter occur extensively throughout the Mediterranean region, being especially well developed in the limestone region east of the Adriatic. They seem to vary in composition, some investigators consid-

ering them mainly as aluminum hydroxides while others consider them to contain a large percentage of aluminum silicates. They have received a great deal of attention during the last few years, but no universal agreement as to their place in the soil scheme of the world has been reached. They are like the red loams in their low content of organic matter but as a rule are heavier in texture and have not been affected by the process of eluviation to the same extent as the red loams. They are developed only in regions of considerable rainfall. They are usually shallow and, when maturely developed, are, like the red loams, free from carbonates.

The Development of Soils

It is believed that soils in course of development are subjected to processes which produce progressive changes in them, the stages of which are best described as those of infancy, youth, maturity, and old age, all of which stages may be found included in any soil family. In order that maturity of soil development may have been reached by the soils of a given area the soil materials must have lain undisturbed through a long period of time. This condition can be attained in general only on fairly smooth surfaces, where the soil material is protected from erosion. In localities where the soil is being removed at a relatively rapid rate the soil is perpetually rejuvenated by having its upper part removed as rapidly as it advances in age. Here, then, is shown the importance of topography in soil development. Soils on hilly land may remain perpetually young on account of the continued erosion, while soils on flat land age rapidly and reach an advanced stage of development in a short time as measured in terms of erosion cycles. Soils are designated as mature which have reached a stage of development marked by the practical absence of geological features and the great predominance of characteristics acquired during development. After maturity the development is marked mainly by the assumption of certain subsoil characteristics, such as compaction and the formation of hardpans.

Soils, then, are developed from soil material consisting of

geological deposits of various kinds directly through the operation of climatic forces, of which rainfall seems the most important, and indirectly through the influence of native vegetation. The development is through the various stages of infancy, youth, maturity, and old age and can take place only where erosion is relatively inactive. The broad general characteristics of the soil at any spot at any time is due to the climate of the locality if the soil is mature. If the soil is immature it will be influenced by the nature of the geological formations, and the immaturity may be due to the topography.

As has been mentioned, American investigators have gone far in showing the intimate relation of soils to topographic features and to stages of development. Human civilization has not endured for a sufficient length of time to enable us to trace the development of the soil on any one spot from infancy through youth to maturity, much less to old age. The identification of soils in such stages, therefore, and the proof that such a development is taking place is a matter of interpretation rather than of observation or demonstration. The various conditions of soil that the student meets within restricted areas where uniform climatic conditions prevail are most rationally explained by assuming that they represent different stages of development of what at maturity would become one thing, rather than permanently and fundamentally different individuals. The features marking the several stages in the development of soils are not the same in all soils but differ according to the major soil group into which a given soil is developing, or, in other words, according to the character of the prevailing climatic, vegetational, topographic, and geologic conditions; so that, throughout their entire course of development through youth, maturity, and old age, the soils in a given soil area, or within a region where the mature soils belong to a single major group, will possess more features in common, at any stage, than they possess in common with the soils of any other soil group. All soils, therefore, of a given soil region, including those in all stages of development, constitute what may be called a soil family. On the other hand, the char-

acteristics of embryo soils, since they are nothing more than freshly accumulated and unchanged geological material, will depend entirely upon geological processes and may be like the characteristics of certain embryo soils in other families and unlike those of other soils in their own family. But, as soon as development has begun to change their embryonic features, they assume, with more or less rapidity, the features characterizing the members of their own family, until, when maturity is reached, the geological features are masked entirely by, or have become very subordinate to, the features assumed during development.

CHAPTER VI

THE STUDY OF AFRICAN SOILS: PAST CONTRIBUTIONS AND THE PRESENT ATTEMPT

History of the Study of African Soils

The distribution of the great soil belts over the continent of Africa seems to have received hitherto no attention whatever. No book, paper, paragraph, or sentence dealing with this matter as a whole has been encountered, nor has any reference to the possibility or probability of the existence of a series of soil belts covering the continent been found. The early explorers, like all men of their kind, interested themselves in the position, character, and extent of the various surface relief features and in certain general references to the native vegetation and finally and mainly in the various features characterizing the native population. In the subsequent period of scientific exploration many expeditions were organized and sent out fully equipped with materials and with trained men to investigate the geological, zoological, botanical, anthropological, and other natural features of the continent; but an expedition, scientific or other, equipped with a trained soil scientist has yet to be organized and sent.

EARLY EXPLORERS

The literature of the early African explorers may be followed through many thousands of pages without rewarding the reader with anything more definite in regard to the character of the soil than an occasional statement that it is red. Such a statement is worthless, because soils of the most diverse characteristics, both as natural bodies and as producers of plants, are red in color. The mere fact of redness is of no more significance in determining the character of a soil than are certain features of dress of civilized man a reliable basis on which to classify him

into natural groups which will express his history and his efficiency. So far, therefore, as any data are concerned on which either the characteristics, the productivity, or the distribution of the soils of the continent can be based, the literature covering the period of early exploration in Africa may be discarded entirely.

SCIENTIFIC EXPEDITIONS

During the last two decades of the nineteenth century a number of well-equipped expeditions were sent to Africa for the scientific investigation of the natural history of the continent on the ground and for the collection of material to be more thoroughly and carefully studied in the laboratories and museums of Europe and America. Many of these expeditions were fully equipped and accompanied by men who were specialists in their lines of work. The results of these expeditions were of great value to science along many lines, but they did not materially advance our knowledge of the soils of the continent. The literature of these expeditions contains references to the soils, but the observers contented themselves in all but a few instances with the designation of the almost universally red soil as laterite. Only in an extremely small number of cases was any attempt made to determine the character of the soils other than to note their red color and to state in most cases that they contained iron concretions and slaglike accumulations of iron oxide underlain by such accumulations. No exact definition of the term used by them other than that such soils were red in color and, when occurring in place, contained iron concretions, had ever been drawn.

AGRICULTURAL EXPERIMENT STATIONS

Since the beginning of the twentieth century a great number of experiment stations and other institutions for the investigation of the agricultural possibilities of their respective regions have been established by the various European colonies on the African continent. But most of these stations have been concerned with experimental work of various kinds, and little attention has been

given to the study of prevailing fundamental natural conditions from a broad scientific standpoint. Their work has been concerned with local conditions, and the methods used, so far as the soil studies made are concerned, have been mainly empirical. Attention has been directed to the determination of the degree of success with which, and the conditions under which, plants of many kinds can be grown by growing them on experimental farms. A great deal of excellent work of this character has been done in the aggregate. Such results can be utilized as such and without further study only in the localities where the studies were made. Before they can be applied to other localities their suitability must be determined by comparative studies of fundamental natural conditions to determine where the conditions are similar to those prevailing in the spot where the experimental success was obtained. Such studies have in no case been based on the determination of the fundamental characteristics of the soils on which the experiments were made. In no case, it seems, with the exception of the station the Germans maintained at Amani in their former East African colony, has the chemical analysis of the soil been carried further than the determination of the percentages of certain soil compounds that are soluble in hydrochloric acid of given strength at a given temperature in a given time. The composition, even in a broad way, of the soils of the several colonies in which the stations are located and by which they are supported has not been determined; so that on this basis comparisons cannot be made for a long time in the future.

GEOLOGICAL SURVEYS

Many of the African colonies have established geological surveys, but these have been concerned almost entirely with the geology of the consolidated substructure of their territory and with their mineral resources. The character of the soil has received no other attention than the usual references, more or less common in geological reports for the last three-quarters of a century, to the assumed close relations of soil character and

geological formation. A paper by Maufe[1] on the soils of Rhodesia gives a short description of four kinds of soils occurring in the province; but no soil map accompanies the paper, and the description of distribution does not enable the reader to make a map of his own that is more than a very general sketch. The soil descriptions are drawn in such a way as to convey very little information that would enable the reader to determine the relation of these soils to those of other parts of the continent. No analyses are given, and apparently none have been made. No full or approximately complete descriptions of the profiles of the various soils are given. The descriptions are about as useful as bases for the identification of the soils as a statement that the trees of a region are deciduous would be as a basis for their identification.

SOIL STUDIES IN SOUTH AFRICA

A great deal of work has been done on the soils of the Union of South Africa, mainly the Cape Province. Several hundred analyses have been made, and many pages of descriptive text and discussion of the results have been published. Practically all of this work was done by Professor C. F. Juritz[2] of the Department of Agriculture of Cape Colony and later of the Union. With him were associated a number of collaborators and assistants. The total amount of work done both in the field and laboratory, especially the latter, was very large, and the results have doubtless been of great value to the agriculture of the region covered. It is unfortunate, however, that they supply practically no information that can be used in determining the fundamental character of the soils or of their distribution. The location of the samples is given, but the descriptive text contains no reference whatever

[1] H. B. Maufe: The Soils of Southern Rhodesia, *Rhodesian Agric. Journ.*, Vol. 14, 1917, pp. 8–23.

[2] C. F. Juritz: The Agricultural Soils of Cape Colony: Investigation and Analyses, *Agric. Journ. of the Cape of Good Hope*, Vol. 33, 1908, pp. 33–45, 171–187, 318–335, 473–490, 599–613, 743–759; Vol. 34, 1909, pp. 64–90, 166–184, 277–294, 422–436, 550–567, 675–697. Cape Town. (Subsequently published in book form under the title "A Study of the Agricultural Soils of the Cape Colony," Cape Town, 1909.)

Idem: Recent Soil Investigation in the Cape Province, *Agric. Journ. of the Union of South Africa*, Vol. 5, 1913, pp. 856–870; Vol. 6, 1913, pp. 38–49, 337–345, 455–461, 785–791, 934–939; Vol. 7, 1914, pp. 62–67. Pretoria.

to the distribution of soils similar, in each case or in any case, to those from which the sample was collected; nor does it describe the relation of the soils sampled to the topography in such a way that their distribution can be determined. No profile drawings of the soils sampled are published. In most cases the depth of the horizon sampled is not given; and very little attempt is made to describe the soil color, the character of the subsoil, or the presence of zones of carbonate accumulation. An elaborate attempt is made to correlate the chemical character of the soil with the geological formations, apparently on the assumption that the character of the geological formations has determined the character of the soils, with a complete disregard of the extreme variations, within the region covered, in the character of the climate. Our experience in the United States would justify us in stating without hesitation that the effect of the geological formations in determining the character of the soils is negligible in comparison with that of the widely varying climatic and topographic conditions.

Not only is the descriptive part of Professor Juritz's work disappointing from the point of view assumed in the present work, but his chemical data are equally so. In no case did he determine the composition of the soil. He merely determined the percentages of certain soil constituents present in such form that they were dissolved by acid of a given strength acting under a given temperature in a given time. In the chemical composition of a soil there are a few things that from the point of view of soil type identification are vitally important. These are: (1) the total percentages present of each of the alkalies and alkaline earths; (2) the total percentage of carbonates, especially lime carbonate; (3) the total percentage of alumina; (4) the percentage of combined water; and, in many cases, (5) the percentage of combined silica. Not one of these requirements is satisfied by the results of Juritz's work, with the possible exception of the carbonates present. Even in this case there is a total lack of information as to whether the lime shown to be present—most of which is presumably present in the form of carbonate—is residual carbonate

from the parent rock or is accumulated carbonate or *Steppenkalk*.

It is well known that the making of complete chemical analyses of soils or rocks is a slow and costly operation. It seems extremely unfortunate, however, that so great an amount of work as that under consideration should have been done in such a way as to furnish to the scientific world so little information of value. The acid-soluble method of making chemical analyses of soils has nothing whatever to recommend it except its supposed value in determining the amount of "available" plant food in the soil. Yet there is by no means unanimity of opinion among chemists as to the truth of this supposition.

SOIL STUDIES IN OTHER PARTS OF AFRICA

Exactly the same situation exists with regard to the chemical work on soils done by most of the other agricultural workers in Africa. Wohltmann[3] has published the results of a great number of analyses of soils from the former German East Africa, all of which were made by the acid-soluble method. The work of the Belgian stations, which has been considerable, is mainly of the same kind. Because of their lack of positive value, no attempt has been made in the present work to enumerate the places where these results have been published.

The situation with regard to the publications of all the other British territories in Africa and the publications of the French, Italian, and Portuguese colonies is exactly the same as with those of the Union of South Africa. The work of the stations of all these colonies is unfortunately hampered by the universal predominance of the practical point of view. In no single case has there been published a description of a soil profile or a complete soil analysis.

It is unnecessary to discuss in detail the publications relating to soils issued by the agricultural experiment stations maintained by other colonies. In none of them are there any chemical data

[3] Ferdinand Wohltmann: Die Ergebnisse der chemischen Untersuchung deutsch-ostafrikanischer Böden, *Der Tropenpflanzer*, Vol. 1, 1897, pp. 129–133. Berlin.

that can be used with full confidence in the identification of the soils of the continent. In some cases, such for example as the recent papers by Smit,[4] the descriptive matter presents important data, although the chemical results, obtained by the acid-soluble method, are of little value.

A considerable body of information in the aggregate has been published in the various reports, official and private, on the geology of Africa. In most cases the chemical data contained in these reports are more valuable than those in the agricultural reports, since most of them consist of complete analyses. The descriptive information is much less valuable, since in most cases it is geological rather than pedological. These publications as well as those published by the agricultural journals and official reports will be cited in the following pages. In the aggregate a large volume of literature is in existence. Its value along many agricultural lines is incalculable. Its value for determining definitely the character of the soils of the respective colonies is almost nil.

SOIL SAMPLES COLLECTED FOR THE PRESENT WORK

During the years 1919–1920 Dr. H. L. Shantz, of the U. S. Department of Agriculture, collected some samples at widely separated places along a belt extending from the Cape of Good Hope to Cairo (for locations, see map, Fig. 1, p. ix). Analyses of a number of these samples have been made in the laboratories of the Bureau of Soils of that department and have been used in differentiating the soils on the accompanying map (inset, Pl. I). The results of these analyses will be found in their proper connection in the following pages.

The Principles Followed in the Present Work in Delimiting the Soils of Africa

THE PRESENT SOIL MAP OF AFRICA

From what has been said it will be evident to everyone that it is impossible at the present time to construct a soil map of Africa.

[4] B. J. Smit: Representative Transvaal Soils, *Journ. Dept. of Agric., Union of South Africa*, Vol. 2, 1921, pp. 170–176, and Vol. 3, 1921, pp. 337–342. Pretoria.

It is not impossible, however, to construct a map in which the probable location and trend of the great soil belts are shown. In the study of the soils of Europe and America certain general principles have been worked out governing the relations of climate, vegetation, geology, and topography to soil character. Through the applications of these principles, modified by such specific information as could be obtained from the literature available, it has been possible to construct the map accompanying the present work (inset, Pl. I).

It cannot be considered a real soil map. It should be considered merely a statement of the possible distribution of the soils. Its value lies not in what it shows but in what it offers by way of suggestion to future investigators and travelers. If it serves to direct the attention of these men to the soil and in this way build up a body of knowledge of soil character as such, it will have served its purpose. If, in the future, investigators may be led to draw descriptions of the soil profiles with as much care as the geologist draws his descriptions of outcrops, a great deal will have been gained. If we can obtain careful descriptions of soil and subsoil color, of the presence of zones of carbonate accumulation, of zones of complete or incomplete oxidation, of the depth to which soil horizon development has extended, and, as a corollary, of the depth to the disintegrated or unchanged parent rock, as well as descriptions of the character of the native vegetation, an important advance will have been made. If such information could then be supplemented by samples, collected strictly with reference to the soil horizons, definite information would be gradually accumulated on which a real soil map could finally be based.

THE DOMINANT INFLUENCE OF CLIMATE ON SOILS

The general principle that the character of the soil at maturity is due mainly to climatic forces and to the character of its native vegetation has become widely accepted within the last few years. It is also well known that topographic conditions constitute an important factor in determining the rate of development and, to a limited degree, the features of the soil at maturity.

The character of the soil in the early stages of its development, as has already been said (p. 130), is determined to a considerable extent by the character of the parent rock, whereas in its later stages climate and vegetation are of predominant influence. The geological conditions are the dominant influence while the soil is in an infantile condition and become less and less important as development proceeds. Experience shows, however, that the soils of that part of the world already more or less carefully investigated are predominantly mature or approaching maturity and indicates that the area of very young soils, those in which the geological features determine the character of the soil entirely or nearly so, is relatively small. In one respect, that of soil texture, it should be noted, however, that geological features or the mineralogical character of the parent rock influence the soil to a rather late period; even in this case climatic conditions are equal if not predominant in their influence from maturity of development onward.

On the basis, therefore, of the known relation of soil character to geologic, climatic, botanic, and topographic conditions, aided by such data as are available from the sources already described, the attempt is made in the following chapters to describe the general character and show the general distribution of the broad soil regions of Africa.

THE PROPER CRITERIA FOR SOIL CLASSIFICATION

Before entering on this description it may be well, however, to take up briefly the question of what, within the modern conception of soil science here outlined, the proper criteria should be for the classification of soils. The soil groups themselves, so far as established, have already been discussed (pp. 121–128).

Soils, like most natural objects, may be classified on a number of bases or groups of bases. When a certain group of related bases has been selected, the one to which primary significance is given sometimes seems to be a matter of indifferent choice; but a logical or scientific classification must recognize that feature or characteristic, of whatever kind it may be, which will group the objects

to be classified into the smallest number of groups possible, or conversely, into a series of groups each of which would include the greatest possible number of individuals and the greatest possible number of related characteristics, no one of which is more nearly related than the others of the group to the members or subgroups of any other of the major groups. Each major group likewise must be divided into subgroups on the basis of features having the same relation to other features as those utilized in the primary grouping, and so on downward through the various steps of the grouping to the individual unit.

While this is the basis on which most natural objects have been classified for a long time, it is not the basis on which, until recently, soils have been classified; and, at the present time, soil literature, when referring to classification, more often refers to a grouping based on the old criteria than to one based on the characteristics of the soils themselves. The statement is often made that the basis heretofore used has been that of origin and that this is the basis on which other natural objects are usually classified. It is true that in the discussions of classifications the word origin is frequently used, but not always, it seems, in the same sense. In the case of most objects a classification on the basis of origin is merely one in which the succession of features assumed in the evolution of the objects is accepted as a basis. The term origin in none of the usual scientific classifications refers to the source of the material of which the objects have been made; yet, in the so-called classification of soils on the basis of origin, this is the only meaning to be given to the term. In its rather widely accepted sense it refers to the geological origin of the inorganic material of which soils are made and is comparable to, and as valuable scientifically as, a classification of animals according to the kinds of food eaten by the various groups. A workable classification of soils must be based on soil characteristics.

The soil features of fundamental importance in the identification of soil units in detail are many; but those on which a broad grouping such as is attempted in this paper is based are relatively few. They consist in the percentage of organic matter in the

soil, expressed in the darkness of the soil color; in the degree of soil drainage and aeration shown by the uniformity of the oxidation color; in the extent of weathering and the depth to which it has extended, expressed by the degree of oxidation of the iron; in the presence of a zone of carbonate accumulation, usually lime carbonate, in the soil section; in the extent to which the soil has been leached of the carbonates that may have been present in the parent material; in the extent and thoroughness of decomposition and leaching, usually determined only by chemical analysis and the presence of *caliche* and other kinds of subsoil induration.

Not all these have been definitely determined for many spots in Africa. Not all of them are needed for every spot, but all of them are needed in the continent as a whole, some in one locality and others in other localities. In most cases, however, the literature refers to a single characteristic, this being usually the soil or subsoil color, mainly the latter, since in Africa it is predominantly red and therefore noticeable. In some cases also the occurrence of carbonates in the subsoil is noted.

CHAPTER VII

THE SOILS OF TEMPERATE AND SUBTROPICAL AFRICA (SOUTH AFRICA, SUDAN, ATLAS REGION)

The Brown Soils of the Southern Cape Province and the Atlas Region of North Africa

The brown soils of the Cape Province include the humid, timbered, or brush-land soils of the intermontane valley lands near the southern coast and a considerable part of the dry-farmed agricultural lands of the Province. The soils are brown to reddish brown in color, with brown to reddish brown subsoils, apparently leached, throughout most of the area at least, of the parent rock carbonates when such existed and in which, mainly, and probably entirely, on account of the moderate to heavy rainfall, no accumulated carbonates have been formed. The content of phosphoric acid, potash, and nitrogen, as in average timbered soils the world over, is low, owing both to leaching and in South Africa, in many cases, to the poverty of these materials in the parent rocks. The textures vary widely. They seem, however, to be predominantly loams and sandy loams. Their general distribution is shown on the map (inset, Pl. I) and needs no description. The country consists of a series of elongated mountain ridges, apparently steep and narrow, with outstretched lowland belts between. The extent to which the floors of these belts are covered with material washed from the bounding ranges is not known, but the greater part of the soil material of these lowlands, that part of the area where agriculture is carried on, seems to be developed from or to consist of this material. In either case the general broad characteristics of the soils would be the same as described above.

The climatic and topographic conditions, geological forma-

tions, botanical features, and such data as can be gathered from the partial chemical analyses and extremely fragmentary descriptions in the literature, show clearly that the soils are very much like those of the Coast Range region of California. None of the soil literature so far as it has been examined describes the presence in these lowlands of such subsoil features as the hardpans found in the Coast Range valleys. These features, however, are not found in California in the humid soils but are confined to the regions of low precipitation. If they occur in South Africa in areas comparable in character to those in California they would apparently be found only in the Little Karroo and in the basin around Worcester. Even here they would be present only in the mature soils and those that are older, if we are to base our estimate on their occurrence in California, where they are invariably associated with soils in those stages. The failure to mention them would indicate that a large part of the agricultural soils of this region are relatively young.

Professor Juritz mentions[1] the presence at various places within this region of dark-colored soils. They seem to occur mainly near the northern and eastern boundaries of the region, though any inference as to the general distribution of such soils from the known data is liable to be erroneous. The described areas seem to be distributed along valley bottoms and in the lowest places, where the moisture is greatest. Professor Juritz's analyses[2] show these soils to be invariably higher in lime than the light-colored soils, indicating either that they belong in the same group as the chernozem soils of Russia, Siberia, North, Central, and South America, and India or in the group of dark-colored swamp soils. The data available, however, do not warrant a definite conclusion as to which of these two groups they belong to. The lime content and moderate rainfall of the region would seem to indicate their close relation to the chernozems if the lime they contain be present, as is presumably the case, in the form of car-

[1] C. F. Juritz: The Agricultural Soils of Cape Colony: Investigation and Analyses, *Agric. Journ. of the Cape of Good Hope*, Vol. 33, 1908, pp. 322, 474, 475, and 608; Vol. 34, 1909, pp. 72, 73, and 288.

[2] *Ibid.*, Vol. 33, 1908, pp. 322, 476, and 609; Vol. 34, 1909, pp. 75–76 and 290.

bonate. On the other hand, where these soils are alluvial in origin, the lime may be derived from the calcareous soils of the Karroo, and, so far as these soils are concerned, the lime may be geological in origin and not due to the operation of soil-making forces. The organic matter, in case they be chernozems, would be preserved because of the effect of carbonates in retaining soil organic matter. In the other case, its preservation would be due to the presence of excessive moisture.

It is possible as well as probable that soils belonging to both of these groups are included in these dark-colored Cape soils, since, theoretically and in accordance with a relationship known from soil studies to be universal in the northern, southern, and western portions of the United States, a belt of black or chernozem soils should occur along the northern part of the belt of brown Cape soils. Those areas of dark-colored soils described[3] by Professor Juritz from near the northern boundary are probably from areas where these soils have been developed, while other areas farther south could well belong to the swamp-soil group. A sample collected by Shantz at Kenkelbosch near Port Elizabeth in 1919, not yet analyzed, is dark in color and shows by the character of its reddish-brown upper subsoil that it is not from a swampy or even from an exceptionally wet area. The deep subsoil was not collected, so that the presence or absence of a carbonate horizon was not determined. Some of Professor Juritz's analyses show that carbonate must be present in considerable quantity in some localities.

On account of the rapid decrease in rainfall from the relatively high precipitation on the coast and on the narrow mountain ridges to the very low rainfall in both the Little Karroo and the Great Karroo (inset, Pl. II) a continuous belt of black soils lying between the brown Cape soils and the desert soils of the Karroo probably does not exist, although with a wider transition belt its presence would be expected. The presence of all the soil belts, each with a fullness of development sufficient to make its identification possible, is to be expected only in those places where

[3] *Ibid.*

the change from low to high moisture is gradual and the topography is sufficiently smooth to enable the soil to lie in place long enough to attain maturity of development. Neither of these conditions seems to be present in the whole stretch of the Cape-Karroo transition belt. There can be but little question that dark-colored soils equivalent to the black earth of Russia, America, and other parts of the world occur in spots along this line; and dark soils developed under humid conditions from excess of moisture are probably present within the area of the brown soils of the coastal belt.

Some areas of dark-colored soils are noted by Professor Juritz,[4] but when their origin is discussed or implied in his descriptions they are identified by him as playa soils, implying that they have developed under excessive moisture conditions and that their dark color is due to the preservation of organic matter from decay by the presence of excessive moisture. Some question may be legitimately raised as to this implied interpretation because of the fact that these are the soils which usually contain, according to Professor Juritz, a higher percentage of lime than any other, in some cases running high enough to suggest accumulations above the amount that should be found in the parent rock. The further fact that all dark-colored soils in the British territories in Africa, whatever their origin or processes of development, are usually described as playa soils and that their dark color, where any attempt is made to explain it, is ascribed to the presence of excessive moisture, is an added reason for questioning the interpretation; since in America dark-colored soils developed under excessive moisture are never calcareous except in those cases where the presence of lime is to be referred to the parent rock. There is no such thing as accumulated lime in such soils occurring in humid regions or, in other words, in regions where their dark color distinguishes them from the well-drained soils around them. It is, moreover, so highly probable as to amount practically to a certainty that some of the black soils of the Transvaal, whose dark color is often ascribed to the effect of excessive moisture, in

[4] *Ibid.*

fact owe their blackness to deficiency rather than to excess of moisture, as will be explained below. The climatic conditions under which these soils have developed in the Transvaal do not differ from those obtaining along the northern part of the area of brown Cape soils to any greater extent than the differences found to exist in America in the climatic conditions over different areas of soils seemingly much like these.

An analysis, published by Wohltmann,[5] of a sample of soil from near Cape Town collected by Pechuel-Loesche, shows a very low percentage of alkalies and alkaline earths with a rather high percentage of iron and alumina. It shows an advanced stage of leaching; but, in the absence of more detailed information, regardless of the rather high rainfall of the district, it does not warrant the statement that there is any important development of hydroxides in the region.

The predominant soils of southern Cape Province, here designated as brown Cape soils, are humid soils developed under a moderate rainfall but without the winter protection of a snow cover or freezing. They are leached of their carbonates, as a rule, and have a moderate to low percentage of lime, potash, phosphoric acid, and nitrogen. They seem to rank with the humid soils of California developed under 20 to 30 inches of rainfall, are moderately productive when carefully handled, but require fertilization when used at all intensively. The rainfall varies considerably in the Cape region, and where it is low the soils seem to show a higher percentage of the mineral plant foods. The alluvial soils of the larger river valleys have been transported in part from the dry regions of the interior, especially the Little Karroo, and contain higher percentages of lime carbonates than the residual soils.

The mountain ridges in the Atlas region of North Africa have been colored to show the presence of soils identical with those of the Cape. This has been done wholly on the basis of the presence of timber in this region and the relatively high rainfall

[5] Ferdinand Wohltmann: Die natürlichen Faktoren der tropischen Agrikultur und die Merkmale ihrer Beurteilung, Leipzig, 1892, p. 147. The analysis is cited under I in the table on p. 218.

(see inset map, Pl. II) that makes timber growth possible. Such information as is available indicates that the lowland belts between the mountain ridges in this region are not covered with the same soils as the ridges. The rainfall seems to be too low. There seem to be no published data on the actual characteristics of the soils of these timbered mountain ridges in North Africa.

The Natal Loams

East of the Great Fish River topographic and climatic conditions change. The rainfall as a whole is higher than in the Cape region, and the ridge-and-valley topography of the Cape is replaced by another type. Instead of parallel, linear, east-west ridges and valleys, the country from the coast inland for an average distance of about 120 miles and stretching northward along the coast into Portuguese East Africa consists of a long slope extending eastward from the foot of the great scarp which limits the South African plateau, most deeply dissected immediately below the scarp, and becoming smoother eastward to a rolling plain, owing to the erosion of a great number of small streams heading in the scarp front and flowing down the slope to the sea. Longitudinal valley lowlands with their belts of unconsolidated material washed from adjacent mountain ridges do not exist. The coating of unconsolidated material on the surface is due predominantly to disintegration of rocks in place. The rocks range from crystalline igneous, both light and dark in color, to sandstones, shales, and apparently a small area of limestones.

The soils are typical humid soils, having developed under a higher rainfall than the Cape soils, and show therefore a lower percentage, as a whole, of soluble mineral constituents than do the latter. According to Williams[6] and Sawyer[7] the soils consist of red loams, vlei soils, and sandy soils—the latter occurring mainly along the coast. No data are supplied by either author that

[6] C. O. Williams: The Composition of Natal Soils, *South African Journ. of Industries*, Vol. 4, 1921, pp. 177–181. Pretoria.

[7] A. R. Sawyer: Cereals in South Africa, *Cedara Agric. College Memoirs*, Vol. 1, p. 49. Cedara, Natal.

will enable the reader to construct even a rough map showing the distribution of these soils. Those derived from the dark-colored igneous rocks seem to be redder than those of the other groups, but all the red soils seem to be very deficient in lime and low in potash and phosphorus. This is a somewhat unusual relationship in the soils of South Africa, since the soils derived from dark-colored igneous rocks in the Transvaal and at least in parts of Southern Rhodesia have high percentages of lime. It is not an unusual relationship in the soils of America, however, since those in the eastern United States derived from rocks high in their content of lime feldspars are invariably low in soluble lime (soluble in hydrochloric acid). It is a convincing evidence of the predominant influence of rainfall in determining the character of the soil. The high rainfall of Natal has leached the lime and prevented the formation and accumulation of lime carbonate in the soil or subsoil; while the lower rainfall of Rhodesia and the Transvaal, as we shall see later, has promoted its development and accumulation.

The analytical results available are not sufficiently complete to warrant a definite conclusion as to the presence of any considerable percentage of aluminum hydroxides in the soils. The results, such as they are, if any conclusion as to that matter were ventured, would indicate their absence, since the percentage of alumina dissolved in the hydrochloric acid treatment adopted is small.

In a small district in the extreme north-central part of Natal, in the region including Ladysmith and Weenen, the subsoil, according to the authors cited above, contains from 1½ to more than 2 per cent of lime, presumably present in the form of carbonate. This is probably an area of young soil developed on carbonate rocks, the carbonate present in the soil being residual from the parent rock rather than a product of weathering, since all the data available indicate a rainfall too high to warrant the latter explanation.

The lime content of the black vlei soil analyzed by Williams is low, differing in this respect quite markedly from most of the

soils of this character analyzed by Juritz in the Cape Province, especially those in the eastern part. This tends to confirm the suggestion that at least some of the soils so described by Juritz are soils whose dark color is due not to an excess of moisture but rather to a deficiency of moisture, which places them in the same group as the black soils of the Low Veld [8] in the Transvaal and of those at Bulawayo.

A belt of low rainfall trending parallel to the coast extends from the latitude of Pietermaritzburg southwestward a little west of Kokstad, includes Maclear, and continues to the latitude of Queenstown, whence it turns southeastward to the coast at East London (inset, Pl. II). The rainfall at Maclear is 20 inches and in the rest of the belt but little more. It seems that no soils from this belt have been analyzed; but, unless the processes of soil evolution are different in this region from those operating in those parts of the world so far studied from that point of view, this belt must contain either some dark-colored soil with a zone of accumulated carbonate in the subsoil or a belt of reddish soil with a similar carbonate zone. This statement is of course based on the assumption that a considerable portion of the soils of the belt have attained maturity of development. A belt of soil similar to that on the Low Veld in the Transvaal, on the Athi Plains near Nairobi in Kenya Colony, and at Bulawayo, or the red representative of that belt, is therefore shown on the map in this region (chernozem; see inset, Pl. I), and solely on the basis of the rainfall. The soil may range in surface color from light brown to black and in subsoil color from yellowish to red, but where maturity of development has been reached it should have some carbonate accumulation in the subsoil. On account of the rolling topography, however, it is probable that only a small part of the area has attained maturity. Presumably, however, it would approach in character the red soil group of the belt in

[8] The term Low Veld is used throughout the section on soils in this work to designate that area of smooth, nearly flat country lying as a northeast-southwest belt a few miles wide just north of Pretoria. It lies a few hundred feet lower than Pretoria and the High Veld south of that city. Its area is approximately shown on the soil map (inset, Pl. I) by the belt of chernozem soils just north of Pretoria.

which it occurs rather than the black or dark-colored group. This would seem to be in accord with our own experience in Texas, where similar conditions apparently exist.

The soils of Natal, with the exception just noted, are placed in the red loam group, shown on the map, however, as Natal loams, with no attempt to differentiate them on the basis of texture. This group includes the soils along the eastern slope of the continent extending from the region of Grahamstown, Cape Province, northward nearly to Lourenço Marques, with a crescent-shaped westward embayment extending up the valley of the Olifants River in the eastern Transvaal (see inset, Pl. I). In the southern part of the belt they have been derived mainly from the sandstones and shales of the Karroo series of rocks, while in the northern part of the belt the rocks vary more widely in character and include quartzites, limestones, and igneous and metamorphic rocks.

These soils are potential timber soils, and the absence of a timber cover in any part of the belt must be ascribed to other causes than the natural ones of soil and climate, except for the local areas where the soil is too shallow to support trees. General descriptions of the belt in the varied literature concerning it describe it as grassland to a considerable extent, true forest cover occupying only a small portion of it. Evans[9] in his recent paper on the vegetation of South Africa calls the southern and greater part of it the Eastern Grass Veld. He does not mention, however, nor does any literature describing the area mention, the presence of dark-colored soils. Such soils probably exist, corresponding to the prairie lands of our Far West, such as the more humid but treeless portions of the California coastal lands.

On account of the topography of the area in which these soils occur a considerable part of it is covered with shallow soil, and another considerable part consists of rough land. The somewhat higher rainfall of the region and the higher prevailing temperature compared with the Cape coastal belt would cause more thorough leaching and the development of a redder color than in the

[9] I. B. Pole Evans: The Veld: Its Resources and Dangers, *South African Journ. of Sci.*, Vol. 17, 1920–21, pp. 1–34. Johannesburg.

latter. Both these features, however, are balanced, to a certain extent at least, by the perpetual rejuvenation to which the soils are subjected through erosion.

The soils of the belt as a whole must be considered as closely related to the brown soils of the Cape on the one hand and to the red loams of the warmer and moister portions of the continent on the other. They are intermediate in character between the two, their significant features being their light color, reddish subsoil, and freedom from carbonate accumulations in soil or subsoil.

So far as is now known these Natal loams are essentially similar to the woodland soils of the highlands of Abyssinia (designated "red loams" on the inset map on Pl. I). The soils in both regions are young and are kept so through the operation of erosion. The character of the parent rock, therefore, is of much more importance in determining the character of the soils than is the case with more mature soils. The parent rock in Abyssinia over considerable, if not large, areas is basalt and other dark-colored igneous rocks. These produce a very fertile young soil, and the fertility is renewed as the soil is rejuvenated. The soils of a considerable part of Abyssinia, therefore, should be more fertile than are those of the Natal belt. Those not derived from basic igneous rocks probably do not vary widely in productivity from corresponding soils in the Natal belt.

The Soils of the Transvaal Prairie

The eastern part of the Transvaal and of the Orange Free State, not including the low country in the northeastern part of the former province, is bounded on the east by the edge of the great escarpment known as the Drakensberg and on the west approximately by the rainfall line of 23 inches (between the 20 and 30-inch isohyets on the inset map, Pl. II) and consists of a high undulating plateau very similar in relief and not widely dissimilar in vegetation to our own Great Plains country. The topography is smooth as a whole, and the soils seem to have reached a stage of maturity of development, having developed under the influence of a moderate rainfall and a grass vegeta-

tion. The rainfall seems to have been high enough to prevent the accumulation of carbonates but not high enough to leach the soil excessively. The surface color of the soil is dark, though apparently not so dark as are the soils developed under similar rainfall and vegetative conditions in cooler climates. The subsoils are predominantly reddish where considerable clay is present and yellowish where they are light in texture or immature. A bed of iron concretions or iron crust underlies some at least of the area, but the extent of its occurrence is not known. Presumably it occurs in the areas with flat topography. A sample collected by Shantz at Vereeniging on the Transvaal-Orange Free State border shows the horizon of concretions well developed.

The literature on the soils of this region consists of three kinds: (1) occasional references to the soil contained in the reports of travelers, consisting almost entirely of references to its red color, to the areas of sand, or to the occurrence of the iron crust, the latter being usually described as "laterite"; (2) geological reports, consisting of references to the texture or color of the soil, the occurrence of "laterite," and a classification of the soils as granite soils, Karroo soils, diabase soils, norite soils, etc., unaccompanied by profile descriptions and entirely without chemical data; (3) the work of Juritz,[10] Marchand, and Smit, consisting of very brief descriptions concerned largely with the geological origin of the soils,[11] accompanied by chemical data

[10] See footnote 2, p. 134.

[11] It is a source of considerable surprise that the students of soils in South Africa should continue, in their latest publications, to group their soils according to the geological formations in the face of their own results which show that soils from the same kinds of rocks in different places, where subjected to different climatic, vegetational, and topographic conditions, are much more widely different in essential soil characteristics than are those within any one climatic area derived from the widest range of geological formations. Professor Juritz devotes a great deal of time and energy to the discussion of the geological origin of the soils of the Cape but ignores completely the tremendous differences brought about by the wide climatic differences between the humid coastal regions and the arid Karroo. Where the soil differences are recognized they are ascribed to geological causes. Smit in his recent paper on "Representative Transvaal Soils" (see footnote 13 below) continues to base his major soil grouping on the geological formations but seems to recognize that formations (of igneous rocks at least) that are essentially alike in their mineralogical composition supply material for soils that are now widely different. He still does not seem to recognize the wide differences between the leached High Veld soils and the highly calcareous soils of the western part of the Transvaal and of Orange Free State.

obtained by the acid-soluble method of chemical analysis. Marchand[12] publishes the results of the application of this method of analysis on red-brown and heavy soils, medium to light loams, sandy soils, and the Koedoespoort red loams, all from the Transvaal. All these soils are low in lime regardless of the fact that the last-mentioned soil, at least, is derived from diabase containing a high percentage of calcium, while soils of the Low Veld derived from a rock essentially like a diabase in mineralogical composition but developed under a lower rainfall and a different topography have very high content of lime, in this case converted into the carbonate.

Smit[13] and Marchand[14] have recently published papers on the soils of the Transvaal, describing them briefly under the heads of Koedoespoort red loams, Pretoria quartzite sandy soils, and norite black turf and publishing the results of acid-soluble analyses of samples. Like all results obtained by this method they may be accepted at approximate face value so far as the percentage of carbonates is concerned. Where the lime is very low it is evident that no significant accumulation of carbonates can be present, and in South Africa where it is high we are justified in concluding that accumulated carbonates are present since parent-rock carbonates are so rare in occurrence as to be negligible. All the analyses published by Smit show a low percentage of lime, except those covering his "norite black turf," which does not belong to the group of soils now under consideration. Smit's results show the presence in these soils of a fair percentage of the alkalies and alkaline earths, the method used recovering only a portion of these constituents present. The low percentage of lime indicates the absence of any accumulation of lime carbonate, while the fair percentages of alkalies show the lack of the complete decomposition and thorough leaching characterizing soils developed to maturity or later under the influence of a hot

[12] B. deC. Marchand: The Soils of the Transvaal, *South African Journ. of Industries*, Vol. 4, 1921, 181–187. Pretoria.

[13] B. J. Smit: Representative Transvaal Soils, *Journ. Dept. of Agric., Union of S. Africa*, Vol. 2, 1921, pp. 170–176, and Vol. 3, 1921, pp. 337–342. Pretoria.

[14] B. deC. Marchand: The Koedoespoort Red Loam, *Journ. Dept. of Agric., Union of S. Africa*, Vol. 1, 1920, pp. 722–727. Pretoria.

climate and a high rainfall. These soils are intermediate, therefore, between dry-land soils and thoroughly leached soils. They are typical humid soils of the slightly leached, and therefore the better, phase of such soils when evaluated on the basis of the percentage of original constituents still retained by the soil.

On the accompanying map (inset, Pl. I) they are shown as a unit covering the whole area, though it is well known they are not all alike in detail. The darkish brown surface color of these soils is due to development under grass cover, and the absence of carbonates is due to the leaching action of a rainfall higher than 25 inches. The iron concretions and yellowish color are probably indicative of local imperfect drainage conditions. The climatic conditions, the topography, the color of the surface sample collected by Shantz at Vereeniging, and the absence of carbonates indicate that the soil is similar to the soils of north-central Texas and eastern Oklahoma in the United States. They are prairie soils developed under rather high rainfall and moderately high temperature. They are not so thoroughly leached as the soils of our southern Atlantic coast, have a higher percentage of organic matter, and are more thoroughly leached than the soils of the Texas Great Plains. The corresponding soils in the central Mississippi Valley are the black prairie soils of eastern Iowa and northern Illinois. These African soils have developed under a higher temperature, however, and have not accumulated so high a percentage of organic matter.

The same group of soils will probably be found in the high eastern part of Southern Rhodesia where grasslands occur, varying in texture in accordance with the nature of the parent material, though no attempt has been made to show such an area on the soil map (inset, Pl. I).

The soils of the Urundi upland east of the northern end of Lake Tanganyika and those of the highlands west of that lake are grassland soils but seem to have a much redder color in both surface and subsoil than the Transvaal soils. Chemical analysis indicates also a rather high content of aluminum hydroxide in the Urundi soil, a condition that might be expected because of

the high rainfall (about 45 inches; see inset, Pl. II) and their situation almost under the equator. The situation seems to be similar on the highlands west of Lake Tanganyika. Dr. J. Bequaert, chief entomologist of the Belgian Congo, reports [15] the presence of laterite in the high level plateau west of Lake Albert, though his identification is not based on chemical analysis and may not be correct therefore. It is highly probable, however, that areas of soil like that of the Transvaal prairie occur in this region and in Urundi, but they cannot be located from the literature.

Studies carried out in the United States show that soils with the general characteristics of those under consideration are invariably developed where the rainfall is higher than 28 inches in Texas and 22 inches in Minnesota and where for any reason a cover of timber has not occupied the land for a long period of time in the immediate past. Such conditions are found in the Middle Western prairies between the timberland soils of Wisconsin, Indiana, Kentucky, the Ozarks, and eastern Texas on one side and the subhumid black soils of the eastern Dakotas, east-central Nebraska, and central Kansas, Oklahoma, and Texas. They are found also, but in a much narrower belt, between the timberlands of northwestern Idaho and the black soils of the Palouse region of eastern Washington, occupying a considerable area around Nez Perce, Idaho; and they are known to occur in discontinuous belts between the timberlands of the high mountains of the West and the desert valleys and plains around them. The valleys around Custer, S. Dak., and the meadows of the Uncompahgre Plateau are two illustrations of this relationship. If this relationship holds for Africa and in general for tropical climates, a narrow area of soils similar to the Transvaal soils may be expected to occur in a belt stretching across French West Africa past Yarbatenda on the upper Gambia, Bamako on the upper Niger, and eastward. It probably occurs in Nigeria north of the Benue and without much doubt covers a belt extending from the northern tip of the Cameroons eastward including the

[15] In private conversation.

Fort Archambault region and reaching the western rim of the Bahr el Ghazal basin (designated "tropical prairie soils" on the inset map, Pl. I).

The occurrence of such soils is not inevitable in passing from a region of high to one of low rainfall. It is not invariably the case in America. It is due to the more or less accidental occupation of the zone in each particular case by a grass vegetation. The rainfall, topographic, and soil conditions favor a timber cover. Wherever it has not occupied the land the cause must be considered accidental rather than natural. Such regions are potential timberlands, and the existing grass vegetation is not the mature (climax) vegetative covering that would finally occupy such areas if left to the operation of natural processes not modified by man or other more or less accidental influences.

Soils of this kind, if their identification be correct, are the most productive in the United States. They constitute the "corn belt" in Iowa, Illinois, and adjacent states. As the belt of occurrence is followed southward into Texas they become less important as maize producers partly because of the irregularity of the moisture supply. They seem to retain their capacity to produce crops in abundance; but the moisture supply, although rather high in total amount, is less effective than in the northern part of the belt because of the irregularity of its distribution. The conditions in South Africa seem to approach the Texas conditions much more closely than those in the corn belt proper. With good moisture supply they constitute probably the most productive upland soils, taken as a whole, in Africa. The soils developed under lower rainfall than were these are richer, measured in terms of their content of the mineral elements of plant food, but their moisture supply is usually still less favorable.

The Chernozems

A sample of soil collected by Shantz in 1919 from the Low Veld 20 miles northwest of Pretoria[16] has very striking characteristics. The surface is black, the texture throughout is

[16] For chemical analysis, see table, p. 218, under II.

heavy, the subsoil is bluish gray and very high in carbonates notwithstanding the fact of its derivation from a rock that contains no carbonate. Maufe[17] describes soils in various places under the name of "black vlei soils" seemingly identical with this; and Passarge[18] describes black soils on a broad plain running northward and westward from about 40 miles northwest of Palapye, Bechuanaland Protectorate. A sample collected by Shantz in the streets of Bulawayo (Fig. 41) has identical characteristics; another collected northeast of Nairobi (Fig. 42) seems to be the same, although the subsoil was not sampled; and the same statement is true of a sample from Shikaba on the White Nile in 11° N., Anglo-Egyptian Sudan.[19] The subsoil of the sample from Bulawayo has more than four per cent of lime, most of which is present in the form of carbonate.

Some samples reported by Juritz from the southern Cape Province, from the region around Uitenhage near Port Elizabeth, seem to have characteristics somewhat like these soils, but the information given is not sufficient to make identification certain. These soils are here tentatively identified as members of the chernozem group of soils partly on the basis of their physical and chemical character and partly on the basis of their location with respect to climate, as will be described below.

The sample collected by Shantz in the Low Veld northwest of Pretoria departs, in one respect, from typical chernozem as it is developed in the United States and as it is defined by the Russian investigators on the basis of the characteristics of the soil in its type locality of southern Russia. Typical chernozem should have a low percentage of carbonates in the surface soil, while the sample from the Low Veld contains enough to cause effervescence in acid. This would create a presumption in favor of identifying it with the *rendzinas* of the Russians and the *Humuskalkböden* of the Germans—soils with high lime content in surface and subsoil

[17] H. B. Maufe: The Soils of Southern Rhodesia, *Rhodesian Agric. Journ.*, Vol. 14, 1917, pp. 8–23.

[18] Siegfried Passarge: Beitrag zur Kenntnis der Geologie von Britisch-Betschuana-Land, *Zeitschr. Gesell. für Erdkunde zu Berlin*, Vol. 36, 1901, pp. 20–68.

[19] For locations see map, Fig. 1, on p. ix; for chemical analyses see, under III–IV, V, and VI respectively, the table on p. 218.

but derived from the incomplete weathering of limestone, usually marly, the carbonate present being residual from the parent rock and doomed to disappear by the time the soil has attained maturity of development. The black color is not permanent but disappears with the disappearance of the carbonate from the surface soil.[20] These soils are confined to humid regions. The soil with the high lime, presumably carbonate, content in the northwestern part of Natal apparently belongs in this group.

The Low Veld soils, as well as those from the other localities mentioned above, would seem not to be identical with the rendzinas since they do not occur in a humid region and are not developed from a carbonate rock and the carbonate in the subsoil is not therefore residual in origin but has been developed from non-carbonate materials.[21] Its black color, accumulated carbonate, apparent granular structure, and location with respect to climate and topography all point to its identity with the chernozems. The high carbonate content of the surface soil is probably due to the high percentage of calcium in the parent rock, the high percentage of carbonate that was developed from it, and the abundant organic matter. The very heavy texture of the soil is probably also a factor in the matter. Notwithstanding its identification by Maufe, and practically all other investigators who have described it, as a vlei soil and one whose dark color is due to excessive moisture rather than to the influence of lime carbonate in preventing the removal of the humus, this soil is here identified as a member of the chernozem group whose dark color is due to a deficiency of moisture rather than to an excess of it and its carbonates to the processes of soil development rather than to their presence as such in the parent rock.

[20] K. von See: Beobachtungen an Verwitterungsböden auf Kalkstein: Ein Beitrag zur Frage der Rendzinaböden, *Internatl. Mitt. für Bodenkunde*, Vol. 11, No. 3–4, 1921, pp. 85–104. Berlin.

[21] It seems unnecessary to discuss the possibility of a derivation from carbonate material laid down as a mantle over the underlying consolidated rock, even though attempts have been made to explain the widespread occurrence of "tuff" (Hatch and Corstorphine, Cohen; see footnote 28, p. 165) as a geological deposit of recent age, just as our American geologists sought to explain the occurrence of the "mortar beds" of the Great Plains in the same way. The testimony of all the South African geologists is unanimous that the Low Veld soil is derived from the underlying consolidated crystalline rock.

FIG. 40—Section of chestnut-brown soil at Taungs, Cape Province, near the Transvaal border, showing a dark red-brown surface horizon of about a foot, a red horizon of about 3 feet beneath it, and apparently a zone of carbonate accumulation beneath the red horizon. Vegetation type of locality: acacia-tall grass savana. Sept. 30, 1919.

FIG. 41

FIG. 42

FIG. 41—Section of chernozem at Bulawayo, Southern Rhodesia. The surface horizon is a dark, nearly black clay loam. The subsoil below about 4 feet is highly impregnated with lime carbonate. The parent rock seems to be dark-colored igneous (see chemical analysis under III and IV in table on p. 218). Vegetation type of locality: acacia-tall grass savana. Nov. 6, 1919.

FIG. 42—Soil section at Njoro in the Rift Valley, Kenya Colony. Dark-colored soil, with lighter-colored subsoil. Probably belongs in the chernozem group. Vegetation type: tall grass. July 10, 1920.

FIG. 43—Detail of Fig. 41. Heavy clay at top, clay and stone fragments beneath it and the carbonate zone, showing the form of occurrence of carbonate accumulations. The parent rock seems to be shown in the lower right-hand corner.

The Low Veld, the Palapye and Bulawayo country, the Shikaba, Nairobi, and Uitenhage localities all lie in the transition belt between regions of higher rainfall and those of lower rainfall. The parent material seems to vary considerably from place to place, although for the most of the localities it seems to consist of dark-colored igneous rock. The Shikaba sample, however, is not derived from such rock; and the source and character of the material of the Nairobi sample are not known, though it is probably dark-colored igneous rock. The striking as well as interesting fact in connection with all these occurrences is the apparent identity of their climatic position with that of what seems to be identical soil in the United States. One of the most characteristic and continuous soil belts in this country is that extending from the Canadian boundary in the Red River valley to south-central Texas, occupying the belt lying between the annual rainfall lines of 17 and 20 inches in the north and changing gradually to that between 22 and 27 inches in the south. The soils throughout this belt are uniformly dark in color and have a granular structure and a zone of carbonate accumulation in the subsoil, the amount of carbonate and the depth of the zone from the surface varying within rather narrow limits while the character of the parent rock varies rather widely.

The African soil of this type is dark in color, and all accounts and descriptions agree in reporting the presence of abundant lime carbonate in the subsoil. It seems to be confined everywhere in Africa to flat areas or to shallow depressions known as vleis. The large area extending northward and westward from the northeast angle of the Kalahari plateau escarpment northwest of Palapye seems to occupy a large flat plain, and a large part of the Low Veld must be considered a plain rather than a vlei. Maufe mentions the occurrence of "black vlei soils" on the flat tops of sandstone mesas in various places, seemingly north of Bulawayo.

These soils, according to the samples collected by Shantz from the Low Veld and at Bulawayo, are not so black as the Dakota representatives of the American belt but agree quite well, in that

respect, with those of the Texas portion of the belt. In at least one other respect the Texas and African soils are similar. As just explained, these soils, in South Africa at least, occur on flats and in vleis. In Texas likewise they are much more characteristically developed on flats and in very slight depressions. On the more rolling areas in both Texas and South Africa the soils are red. In Texas the subsoils are calcareous, owing to accumulated lime carbonates; whereas in Africa the character of the subsoils is not, as a rule, mentioned, the most direct reference being made in describing the soil southwest of Lindi, Tanganyika Territory. It seems probable that in hot climates decomposition of vegetable matter in the surface soil in spots where the run-off is rapid does not present conditions for the accumulation of that material in the surface soil. The type of rainfall, that of sudden downpours, does not favor the growth of a luxuriant cover of grass. The heavy downpours of short duration do not wet the soil to great depth, as run-off is rapid, and the surface soil dries out in a very short time. On the other hand the run-off from the flat lands is slow, the surface remains moist for long periods of time, the growth of grass is promoted, and the decomposition of the organic matter is much less rapid. Such dark-colored soils, although they occur on flat surfaces and vleis only, cannot be grouped with the prairie soils or with the dark-colored poorly drained soils of humid regions. Their zone of carbonate accumulation, invariably present in the subsoils at no great depth, removes them from the former group; and the total lack of the well-known evidences of poor drainage in the subsoils removes them from the latter.

The conditions in Texas and apparently those in Africa seem to point, therefore, to the conclusion that soils with well-defined chernozem surface characteristics, the dark-colored surface soils, are developed, in southern latitudes where the rainfall comes in the form of heavy downpours, on approximately level areas only. The seasonal character of the rainfall does not seem to be a very important factor in this matter. While the rainfall in Africa is seasonal in its distribution, that of Texas cannot be considered

so, although the greater part of it falls in the spring and early summer. In California, however, the rainfall is strictly seasonal in its distribution, yet soils with well-marked chernozem characteristics occur in the hills around San Francisco and on the smooth lands of the San Joaquin Valley. In the United States the two main chernozem belts differ entirely in this respect. The belt marking the eastern Great Plains border, stretching from Texas entirely across the United States and for a thousand miles at least into Canada, has developed in a region not characterized by a seasonal distribution of rainfall, while the eastern Palouse belt of Washington has developed in a region of pronounced seasonal rainfall. It would seem, therefore, that Maufe's statement: "Black soils are found in countries in which there is an alternation of wet and dry seasons" [22] cannot be accepted as true if he means, by that statement, that they are confined to such regions.

In the Low Veld the dark-colored soil identified as chernozem in this discussion seems to be derived from dark-colored igneous rocks, and the same seems to be true of certain areas northwest of Palapye and those at Bulawayo and apparently those also on the Athi and Kapiti Plains near Nairobi in Kenya Colony. It would seem doubtful whether all the area stretching out over the flat plain from a few miles northwest of Palapye toward the Makarikari basin is derived from the same rock. The high percentage of calcium in rocks of this character would favor the development of chernozem of pronounced characteristics in regions where climatic conditions are favorable.

The calcium does not occur in these rocks in the form of carbonates, while that is the form in which it is found in the soil. In the United States, soils with such characteristics are developed on rocks of this kind as well as on sedimentary rocks of various kinds and on igneous rocks of light color. There is no evidence at hand that would seem to indicate that such soils may not occur on a great variety of rocks in Africa.

The accompanying map (inset, Pl. I) shows the occurrence of

[22] H. B. Maufe, *op. cit.*

soils of this group over large areas of Africa beyond the areas mentioned above. The latter localities are those for which a certain amount of more or less definite information is at hand. The chemical composition of samples collected by Shantz and analyzed by Robinson and Holmes in the laboratories of the Bureau of Soils, together with their physical characteristics, constitutes the sole available information of direct and convincing value. This is supplemented by descriptive information from many sources for the Low Veld region and from descriptions by Maufe[23] for the Athi Plains in a paper of unusual value. All these areas have developed under approximately the same rainfall and stand in approximately the same relation to other soils, especially to the timbered and desert soils. Their relation to dark-colored igneous rocks is made much of by the geologists and by those soil investigators who think of soils only in terms of the original soil material, regardless of the changes that have taken place in it while being converted into soil, and of the amounts of a few of the constituents soluble in hydrochloric acid. Yet that this is not the most significant and influential factor in determining their characteristics is shown by the two facts that over wide areas in Africa these same rocks have supplied material for entirely different soils and that the soils at Shikaba, as well as those along the Sudan-Abyssinian boundary, are not derived from this material. The relation of these soils to the topography is striking, while that to the rainfall is but little less so. They have developed on smooth areas where the rainfall ranges between 20 and 30 inches.

On the basis of this climate-topography relationship this group of soils has been extended on the map over wide areas of which we have no definite information whatever as to the nature of the soil, reliance being placed entirely on the rainfall and the apparent character of the surface relief. A belt runs westward from Bulawayo between the region of higher rainfall and open forest of the upper Zambezi on the one hand and the drier region

[23] H. B. Muff [i. e. Maufe]: Report Relating to the Geology of the East Africa Protectorate, *Misc. Colonial Repts. No. 45*, London, 1908.

of the Kalahari on the other. This region has a smooth, and a great deal of it a flat, topography. A considerable part of the western end of the belt is covered with a parklike native vegetation. Apparently, however, no traveler has described the soil. A narrow belt is extended northward along the Angola coast nearly to the mouth of the Congo.

In the United States there is a continuous belt of soils of this character lying along the boundary between the humid and arid soils. The rainfall is lower than in the former and higher than in the latter. It is the transition belt between the prairie and timbered soils on the one hand and the semiarid soils on the other.

If this climatic relationship holds for Africa there must be a belt of these soils stretching east and west across Africa north of the equatorial belt of humid soils and south of the Sahara. Confirmation of this is found in the sample of soil collected by Shantz at Shikaba on the White Nile, which occurs within the belt having a rainfall intermediate between the humid region south of it and the arid region north of it, the amount being approximately equal to that of the East African areas of this soil.

The abundant French literature on the Shari-Chad region and that part of the West African country lying north of the coastal belt of high rainfall, including the bend of the Niger, is singularly lacking in any description of the soil on which reliance can be placed. There is an abundance of information available for the topography, the native vegetation, the character and density of the population, and the native agriculture—but nothing regarding the soil. There is even a lack of acid-soluble analyses. The information regarding Nigeria is no better.

Notwithstanding this lack of information, a belt of this group of soils is shown on the map extending across the continent from the West coast to the Nile on the basis of conditions known to exist in North America[24] and Europe[25] and the character of the

[24] C. F. Marbut: Contribution of Soil Surveys to Soil Science, *Proc. 41st Ann. Meeting of the Soc. for the Promotion of Agric. Sci.*, pp. 116–142.

[25] K. Glinka: Die Typen der Bodenbildung, ihre Klassifikation und geographische Verbreitung, Berlin, 1914, pp. 258–279.

sample collected at Shikaba. This is imperfectly confirmed by Angoulvant's descriptions[26] of the areas of dense native population and intensive native agriculture in the bend of the Niger.

The belt of country between the 20 and 30-inch rainfall lines (see inset map, Pl. II) which crosses Africa from west to east south of the Sahara may be said to divide into two belts at or just east of the Nile, one area extending northeastward east of the Nile between that stream and the foot of the Abyssinian highland, the other, as an "enclave" of less than 30 inches rainfall extending southeastward toward Lake Rudolph.

The foot of the Abyssinian plateau seems to mark the eastern boundary of the northern area of the chernozem belt in this region. "Black cotton soil" [27] is described from the vicinity of Kassala on the Sudan-Eritrea frontier and from many other places thence southward along the foot of the plateau, the belt apparently becoming wider by extending farther westward until it merges into the transcontinental east-west belt. Although this is described as black cotton soil the term does not seem to have been defined with sufficient accuracy to warrant full confidence in its identification in this region as chernozem. It seems not yet to have been shown that the term is always applied to heavy black soils developed under normal well-drained conditions, with granular structure and a zone of carbonate accumulation in the subsoil. It is probable that it is applied in some cases to dark-colored humid soils both poorly drained and well drained but all lacking subsoil zone of carbonate accumulation. Such soils may be expected in this latitude where the rainfall amounts to somewhat more than 30 inches. It lies well within the range of possibility that a narrow belt of the latter soils, similar in conditions as well as stage of development to those described above as Transvaal prairie soils, lies in this region. If such soils occur they are confined to a narrow belt

[26] G. Angoulvant: Le problème des voies de communication et des débouchés maritimes de l'Afrique Occidentale Française, *Colonies et Marine*, Vol. 4, 1920, pp. 531–563.

[27] The Anglo-Egyptian Sudan: A Compendium Prepared by Officers of the Sudan Government, 2 vols., London, 1905; reference in Vol. 1, pp. 97–120.

lying immediately along the foot of the Abyssinian plateau. This does not necessarily exclude the occurrence of a parallel belt or zone of chernozem along its western side.

Another area of chernozem probably occupies the high portions of the Somaliland plateau. This area seems to have shallow soil, but the native vegetation seems to rank with that in the chernozem belts.

In the Transvaal a number of areas of chernozem have been outlined on the map on the smooth watershed plateaus bordering the western side of the Transvaal prairie south of the Low Veld region. They have been located wholly on the basis of the rainfall, the topography, and the indefinite accounts of the occurrence of "tuff" by a number of travelers.[28] An area or two has been inserted in the northeastern Cape Province and one in southern Natal. There is no basis of actual fact in our possession, other than stated, to warrant the establishment of these areas.

The soils of this group are richest in nitrogen, lime, and phosphorus of all the soils of the continent. Their store of phosphorus is, like that of most virgin soils, low but not lower than that of the soils previously described. It is usually higher, in fact, than in the soils developed under higher rainfall and thereby subjected to more thorough leaching. It is in nitrogen and lime that this soil is especially rich. The soils next to be described contain, all of them, as much lime as this group, and some of them contain more; but none of them is as rich in nitrogen. In productivity, however, these soils are not so high as some of those already described. Their extremely heavy texture, especially in the areas where they seem to be most typically developed, such as the Low Veld and the Athi Plains, render them difficult to work and subject to extreme changes in moisture conditions. They become excessively wet, soft, and sticky during the rainy season, while, on the other hand, in the dry

[28] F. H. Hatch and G. S. Corstorphine: The Geology of South Africa, London, 1905, pp. 265–267.

E. Cohen: Geognostisch-petrographische Skizzen aus Süd-Afrika, *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, Suppl. Vol. 5, 1887, pp. 195–274. Stuttgart.

season they become extremely dry and hard and crack badly, so that the subsoil moisture is evaporated. On the whole they seem less well adapted to the growing of general farm crops than are the lighter soils of the other groups where the amount of the elements constituting plant foods is present in smaller quantity. It seems that an unfavorable physical character in a soil is a much more serious disadvantage in its agricultural utilization than a lack of abundant plant food. The latter is easily and cheaply remedied through the use of fertilizers and animal manures. The former is not easily remedied, and in many cases its fundamental change is impossible.

Light-Colored Soils of the Chernozem Belt

The accompanying map (inset, Pl. I) shows some large areas in the eastern part of the continent, extending from the Cape Province to Kenya Colony, as belonging to the light-colored soils of the chernozem group. The surface layers of these soils seem to be gray, dark gray, brown, ashy, chocolate, and red. They have been described from a number of places in the Transvaal,[29] from Tanganyika Territory, and Kenya Colony along the Uganda Railway.[30] In each case the description refers only to a spot, excepting along the Uganda Railway, and the large areas shown on the map have been extended out from these on the basis of the rainfall and topography. No information of a definite character is at hand regarding the large area shown in Portuguese East Africa and extending southwestward into Rhodesia.

Soils of this character have been described from the Barberton, Bethel, Standerton, Potchefstroom, and Waterberg districts[31] mainly in the southeastern and southern Transvaal. The descriptions consist of a mere reference to the color and texture and the chemical composition determined by the acid-soluble method

[29] Smit, paper cited in footnote 13, p. 153.

[30] H. B. Muff [i. e. Maufe], report cited above in footnote 23. For chemical analysis, see under VII, table on p. 219.

[31] *Union of South Africa, Dept. of Agric., [Ann.] Rept. with Appendices; Report of Chief Chemist*, 1910–11 (Apps. XIX and XX, pp. 373–404), 1912–13 (App. XIV, pp. 297–312), 1913–14 (App. XI, pp. 217–241), and 1917. Cape Town.

of analysis. They are identified on the basis of the acid-soluble percentage of lime reported, on the assumption that most of this is in the form of carbonate. The textures range from heavy clay to light sandy loams and probably to sand. They seem to occur in regions where the topography is rolling to hilly or rougher. The rainfall, in the form of heavy downpours of short duration, falling on such surfaces is mostly lost to the soil by run-off. These soils seem to have the same relation to the black soils of the same belt, the chernozems, as the red or light-colored soils of the chernozem belt in Texas have to the dark-colored soils of the same belt and for the same reason. The low rainfall and the fact that only a small part of it reaches the subsoil promote the conversion of the lime present in the decomposing minerals into carbonate, and the rapid run-off, together with the prevailing high temperature and the long dry season, prevents the accumulation of organic matter in the soil in sufficient quantity to make it black. The black soils of the belt, as already shown, are confined to the smooth lands, where the run-off is not rapid and where they even get some moisture, in some cases at least, from the run-off of adjacent higher and rougher areas. These black soils all seem to be very heavy also, a condition tending to retard the rate of decay of vegetable matter and also to place the subsoils in about the same relation to moisture as those of the rolling lands.

These soils south of the Zambezi probably occupy all the Zambezi hill region extending southward to the smooth lands on the Bulawayo-Salisbury upland, not including isolated plateau remnants north of the upland. In many places these soils will probably have no calcareous accumulations in the subsoil, since, where erosion is active, the soil is not allowed, for that reason, to become old enough to accumulate carbonates. This is the case in the southern end of the chernozem belt in Texas and presumably is the case in Africa. South of the Bulawayo region soils of this character probably occupy all the hilly country along both sides of the Limpopo and its tributaries, extending eastward to the region of relatively high rainfall (30 to 40 inches and higher), where the soils are more thoroughly leached.

As has been stated already, nothing definite is known about the soils of this belt in Northern Rhodesia and Portuguese East Africa. The northern part of the latter colony seems to consist of essentially similar topography, vegetation, geology, and climate to that of the southeastern part of Tanganyika Territory. In this territory a belt of flat-lying sandstones, with some remnants forming low plateaus, occupies a north-south strip some distance back from the coast, the coastal strip being somewhat hilly and varying greatly in its soil characteristics. The sandstone belt is occupied by a very sandy soil, which covers not only the plateaus but large areas of country around them. Beyond (west of) the sandstone belt the rock is gneiss, forming rather sandy surface soil but a compact subsoil into which moisture does not readily penetrate. The subsoil contains, in places at least, deposits of *Steppenkalk*, showing clearly its development under low rainfall conditions.

Maufe[32] described more fully than anyone else has yet done the character of certain soils here interpreted as members of this belt of soils as they are developed along the Uganda Railway. The soils are derived from gneiss and cover a somewhat rolling surface. In its most widespread phases the soil is a bright red sandy earth, the upper two to four feet being more sandy than the deeper horizons.[33] Calcareous nodules are frequently found at a depth of a few feet, being more abundant at or near the lower parts of slopes than elsewhere, presumably because of the

[32] H. B. Muff [i. e. Maufe], report cited above in footnote 23.

[33] This, and many more or less casual references to African soils, suggest very strongly the existence of conditions strikingly similar in certain respects to those under which the soils of our own southern Appalachian Piedmont region have developed, the features in which the resulting soils are similar being more fully developed in Africa apparently than in America. The feature referred to is a light-colored or in some cases a red sand as a surface soil with a heavy clay subsoil. The sand surface is not derived from a sandstone but is the residual sand left after the finer particles originally present as part of the product of rock decomposition, usually feldspathic rocks, have been removed by the heavy rainfall or washed downward into the subsoil. Since the subsoil is little if any heavier at top than it is deeper down it is apparent that the process has been one of removal of the fine material rather than its translocation to the subsoil. Whether this is a process that operates in all warm regions with high rainfall is not known, but many incidental references found in African soil literature indicate its operation on an extensive scale in that continent. Apparently the operation has been more powerful there than here, developing a deeper surface horizon of sand.

accumulation in such places of more moisture than on the slopes or on flats beyond the foot of slopes and because of the evaporation of the water from such situations. The horizon or zone of lime-carbonate accumulation in the soil is not of uniform thickness. It is in some places several feet thick, since, in places where the soil is subjected to erosion and where the overlying sand and red clay have been removed, the lime nodules often occur in masses four or five feet in height and ten yards in diameter.

Maufe, describing the occurrence within the belt of small areas of "black cotton soil," says they occur on flats or places with poor underdrainage. They are most abundant on low land near Makindu and in similar situations near Sultan Hamud, both stations on the Uganda Railway some 60 miles north of Kilimanjaro. It is possible that some or even all the areas of "black cotton soil" described by him are really poorly drained and therefore wet-land soils whose dark color is due to an excess of moisture which prevents rapid decay of the organic matter. However, in a climate as hot as tropical Africa, with a rainfall occurring only in part of the year while the rest of the year is dry and hot, the occurrence of such areas in a form that would not at once be designated as swamps is somewhat doubtful. The further fact that these areas are more abundant in the northwestern part of the belt in which the red soils occur, in a region adjacent to the soils identified in this study as chernozems, lends probability to the suggestion that these are true chernozems developed on smooth areas and should be identified as such. The further fact that Maufe describes the black earths of the Athi Plains as wet-land soils whose blackness is due to excess moisture is a further evidence of the identity of the two soils and of their both being chernozems. The occurrence of abundant carbonate in the subsoil of the Athi Plains and the fact that it is soil carbonate rather than parent-rock carbonate renders it certain that those soils cannot owe their striking characteristics to an excess of moisture; and the probable identity of the small areas of black soils among the red soils farther south make it a practical certainty that the latter are chernozems.

If this interpretation be correct it shows the intimate relation of the chernozems to these red soils and that they really are parts of one and the same belt, their differences being due mainly to a difference in the topography of the surfaces on which they have developed.

The soils of this group have been developed from a wide variety of rocks, ranging from sandstones through metamorphic rocks and light and dark-colored igneous rocks. The character of the rock apparently expresses itself in the texture of the soil only, though it is evident that the soils derived from sandstones have a less well-defined horizon of carbonate accumulation. This statement is based partly on the nature of sandstones in general and partly on the absence of any reference in German literature to the occurrence of *Steppenkalk* in this region.

The soils of this group have a low percentage of nitrogen as a rule; a high percentage of lime, presumably mostly carbonate; a good to high percentage of potash; and a moderate percentage of phosphoric acid. They differ from the black soils associated with them chiefly in their low content of nitrogen. On account of the rolling topography on which they have developed and their normally low rainfall they seem to be less productive than the soils of the groups previously described. They are extensively utilized, however, by the natives for growing crops. The sandstone plateaus and the zones around the larger *Inselberge* of the southeastern part of former German East Africa seem to be rather well occupied by a native population which subsists on native agriculture rather than cattle raising. Under irrigation they should be highly productive. Dry farming is necessarily confined to the rainy season or the period immediately after its close.

The Chestnut-Brown Soils

In those continents where the distribution of soil belts and their relation to climatic belts, topography, geological formations, and native vegetation have been worked out, the belt of chernozem soils lies adjacent on one side to soils developed under rainfall conditions higher than those in the chernozem belt itself

and on the other to soils developed under lower rainfall; except in the evident rare case in which the chernozem belt occupies the trough of rainfall distribution—a case not yet described from any part of the world in which this soil occupies anything more than a local area due to local conditions. No such relationship has yet been described from the great chernozem belts traversing the broad plains areas of any of the continents. A supposed area of this kind is shown running northwestward from the Lake Rudolph region on the accompanying map (inset, Pl. I) though, as already explained, it is so placed merely on the basis of general conditions and not on that of any soil facts in the writer's possession.

The moister belt adjacent to the chernozem is represented in South Africa by the High Veld or, as here described, the Transvaal prairies, the timbered or partially timbered lands of Natal, eastern Transvaal, and Rhodesia, and the open forest lands of Northern Rhodesia whose soils have already been described. In the Kenya Colony a similar moister belt adjoins the chernozem.

The drier belt adjacent to the chernozem is represented, in South Africa, by a belt which extends from the east-central Cape Province, across the western Orange Free State, and along the eastern and northern sides of the Kalahari Desert and, in East Africa, by the eastern part of the Somaliland plateau, the upland which continues the Abyssinian plateau beyond the Rift valley (inset map, Pl. I). The soils of these areas belong to the chestnut-brown group, to be described in this section.

West and south of the chernozem belt in South Africa and east of this soil belt in East Africa the rainfall decreases progressively (see inset map, Pl. II). The rainfall of the chernozem belt is the minimum necessary in the region of its occurrence for the maintenance of a luxuriant grass vegetation, causing the production in the soil of a great deal of vegetation in the form of fine grass roots which readily decompose to the so-called humus state. The rainfall is also not only too low to bring about the removal of such lime carbonate from the subsoil as may have been present in the parent rock but promotes through the action of carbonic acid gas the

development of lime carbonate from the other compounds of calcium that may have been present in the parent rock. By this means it prevents the exhaustion of the lime from the soil and, consequently, prevents the solution and removal of the organic constituents so rapidly as to lighten the color of the soil.

In the adjacent belt of higher rainfall a luxuriant grass cover may develop. But, except in those rare cases where the parent rock consists of a mass which disintegrates into soil too rapidly for the removal of the carbonate as fast as the soil develops in other respects, the rainfall is too high to permit the development of carbonates from the calcium compounds present fast enough to allow them to accumulate. It is high enough, also, to remove rapidly and in a relatively short time, when measured in terms of the period of soil development, the parent-rock carbonates present. Thus it permits a more rapid disappearance of soil organic matter than occurs in the chernozem belt and prevents its accumulation, except in those areas where, because of some accident, such as frequent fires, forests do not develop. In such cases a heavy grass vegetation such as that of the American humid prairies promotes the accumulation of organic matter in the soil and the development of a dark soil color.

In the adjacent belt of lower rainfall than that of the chernozem belt the lime carbonate is still more abundant, and the zone of accumulation lies nearer the surface than in the latter soil. In the latter this zone ranges in depth from 24 inches on the drier margin of the belt to probably 60 inches on the wetter margin. In fact, the latter depth seems to persist to the point where the lime carbonate disappears entirely. In the adjoining belt of lower rainfall it ranges from about one to two feet from the surface on the drier and wetter margins respectively. If the presence of the lime carbonate were the only factor in the production of the black color of the soil, the soils in this belt would be as black at least as those in the chernozem belt; but an abundance of organic matter in the soil is a more important requirement. This can be produced by the native vegetation only, and, since the rainfall is too low for forest growth, it must come from grass or other sim-

ilar forms. This cannot be as luxuriant as in the chernozem or prairie belts. Consequently the organic matter production in the soil is not so high. The color of the soil is, therefore, not so black. It follows, then, that this belt of soils should be dark in color but not black, should have a zone of carbonate accumulation from one to about two feet below the surface, should have structural characteristics much like those of the chernozem, [34] and should, like the latter, display an absence of that clay concentration which is so characteristic of the subsoils of all soils developed under humid conditions.

In Russia this belt is designated as that of the chestnut-colored soils because of a faint reddish brown shade in the soil when seen under field conditions. This color characterizes the belt of soils in south-temperate latitudes mainly, but in more northern latitudes the color is dark brown rather than a pronounced chestnut. In Africa, however, the color ranges from dark chocolate brown to a reddish chestnut-brown. In the equatorial region it seems to be redder than in South Africa.

The description of the native vegetation in the Griqualand West and Kaap Plateau region (north of the junction of the Vaal and Orange Rivers), and elsewhere in the eastern and northern parts of the Kalahari region, when correlated with the rainfall, makes it practically certain that a belt of chestnut-brown soils occurs in this region (Fig. 40). Soil texture in the northern, northeastern, and a considerable portion of the northwestern part of the Kalahari is very sandy, probably a sand or light sandy loam. This condition would tend to give the soil a lighter color and place the zone of carbonate accumulation, if it be present at all, at greater depth than would be the case if the soil material were heavier. The first of these characteristics, the lighter color of the soil, would approximate conditions found in a drier climate, while the latter would approximate exactly the opposite conditions. The normal chestnut-brown soil should occur on the pla-

[34] Recent studies in the western United States indicate that the granular horizon so characteristic of the chernozems fails entirely in the chestnut-brown soils, although the evidence so far accumulated does not warrant a positive statement to that effect.

teaus of former German Southwest Africa,[35] the Kaap Plateau, and the east-central Cape Colony south and southeast of Kimberley.

Chestnut-brown soils are shown on the map in these areas on the basis of the theoretical considerations just described, together with the meager data from other sources, such as the character of the vegetation and a note by Shantz to the effect that the soil at De Aar Junction in the Cape Province is dark brown in color in the surface soil and has a gray zone at a depth of about 18 inches. Presumably the latter is a zone of carbonate of lime.

The same theoretical considerations that seem to warrant the placing of a zone of chestnut-brown soils alongside the supposed chernozem zone in South Africa must be applied to a zone running east and west along the south side of the Sahara. If our actual knowledge, however, about the Kalahari border is meager, knowledge of the Sahara border is still more so. No single sentence has yet been found in all the examined literature of the region that will warrant the placing of such a zone in this place on the basis of direct statement of fact or even of inference from indirect statement. Actual information as to the soil characteristics is nil. Such references to the soil as exist concern texture or chemical composition of the surface horizon obtained by the acid-digestion method, which for our purposes is worthless. No reference to the occurrence of carbonates in the subsoil has been found.

Although no statement has been found in the literature justifying the placing of a belt of chernozem soils across this part of the continent, yet, on the basis of the conditions described under that head, the belt, as previously stated, has been placed on the map. If we are justified in establishing the one belt, failure to establish the other could be justified only on the basis of direct and specific evidence against its occurrence; for the climatic conditions are identical, so far as relative moisture supply and topography are concerned, with those in other parts of the world where the two belts invariably occur side by side. If these two

[35] The plateaus of former German Southwest Africa which rise high enough to permit the development of this soil are so narrow that the areas are too small to be shown on the soil map (inset, Pl. I).

soil belts are not closely associated here and do not occur side by side, their failure to do so must be due to conditions to which attention has never yet been called. Otherwise our climatic-soil relations—known to be constant, within limits, for other parts of the world—are not constant for all parts of it. All the indirect evidence, from whatever source, that can be brought together concerning the region seems to justify the conclusion that such a soil belt in some form must occur here. The texture of the belt is unknown, but there are presumably large areas of light-textured soils present in it. Such references as are contained in the literature describe considerable areas of sand south and southwest of Timbuktu, but in the Nigeria region it seems to be less abundant. Along the Nile, within the supposed limits of this belt, the soils seem to be relatively heavy.

The occurrence of dark-colored soils, presumably chernozems, in Kenya Colony has been noted above in the section on the chernozem. Eastward and northeastward from this chernozem area about Nairobi the rainfall decreases (see inset map, Pl. II) until desert conditions obtain over the lowlands of Somaliland. The sample of black soil collected by Shantz northeast of Nairobi (V in the table on p. 218) had developed under a rainfall seemingly somewhat greater than that in the Low Veld of the Transvaal, but it had also developed under a hotter climate, so that the effective soil moisture supply in the two places is presumably not widely different. The native vegetation and the abundance of wild game in considerable portions of the Kenya Colony indicate that east of the region of black soils there is a broad belt where conditions would favor the occurrence of a shallow carbonate zone in the soil and a dark-colored surface soil in grassland areas. We have little direct evidence of the presence of a good grass cover on the lowlands of Somaliland, but the evidence seems to be very good that the high plateau extending northeastward from the Rift Valley northeast of Lake Rudolph is covered with a good growth of grass. There is some indication in some of the meager literature of the region that chernozem occurs in favorable locations along the higher portions of the plateau. Although direct

soil facts do not exist in the literature, yet there can be no question that the eastern part of the high plateau of Somaliland is covered with a chestnut-brown soil or its equivalent in productiveness and other characteristics.

This broad belt, which includes with the chestnut-brown soils the light-colored soils of the chernozem group, as shown on the map and as explained below, extends southwestward to the vicinity of Lake Rudolph at its southern end, thence southward and southeastward around and to the east of Mount Kenya. The Uganda Railway traverses it in the stretch lying between mile post 283 and the vicinity of Tsavo.[36] It extends thence southward, varying in width mainly according to the topography, to the vicinity of the railway across the Tanganyika Territory. The Somaliland portion of the belt is derived to a considerable extent from limestone, the southern part from gneiss and sandstones.[37] The mapping finally decided on is based on the description of the soil along the Uganda railway by Maufe.[38] The predominant soil is red. Maufe's description applies mainly to the subsoil, which contains abundant lime concretions. This latter fact removes it immediately and unconditionally from those red soils found in most parts of the continent which are developed under the influence of a high rainfall and until within the last few years were universally described as laterite. It is not laterite nor nearly related to it.

[36] H. B. Muff [i. e. Maufe], report cited above in footnote 23.

[37] It is probable that this belt includes areas that belong more properly in the belt of chernozem soils than in that of the chestnut-brown soils. The western part of the Somaliland plateau has a rainfall of 30 inches; so also does the western part of the zone south of Lake Sugota (which lies in the continuation of the Rift Valley south of Lake Rudolph). In Southern Rhodesia and the Transvaal this rainfall is apparently higher than that in which even the chernozems develop and corresponds to that of the prairie soils of the eastern Transvaal. In Texas no chernozem has yet been identified in a region with 30 inches rainfall; and the chestnut-brown soils of the state are invariably found, so far as is now known, where they developed under a rainfall of 23 inches and less. It is not possible, with our existing knowledge of the subject, definitely to evaluate, in terms of the influence on soil development, the differences in type of rainfall and of temperature. It does not seem probable, however, that the chestnut-brown soils in the East Africa and Somaliland regions would require 10 inches more rainfall for their development than those of Southern Rhodesia and the Transvaal.

[38] Report cited above in footnote 23.

Maufe describes a black soil,[39] associated with the red soil, occurring on flats where it receives some run-off from neighboring localities and on account of its topography retains a greater proportion of its own rainfall than is retained on the more rolling lands. Maufe explains such soils as due to their high moisture content, just as he explains the black soils on the Kapiti and Athi Plains as due to the same condition. This explanation is correct, but the inference that he seems to draw that the black soils are due to excessive moisture, as is the case with the dark-colored soils of northern Europe, is not correct. They show no evidence of imperfect subsoil drainage such as is invariably shown by the dark-colored wet-land soils referred to; and the latter are invariably free from accumulations of lime carbonate, while these black African soils have abundant carbonate accumulations. The occurrences of marl beds beneath lake beds or beneath soils derived from filled lake beds cannot be ascribed to the same processes as those operating in this region. These areas are not covered with lake deposits. The conditions seem to be similar to those in the western part of the chernozem belt of Texas, where the dark-colored soil is confined to areas of flat topography, while on the rolling areas the soil is red. The rainfall comes in heavy downpours and runs rapidly off the rolling areas. It remains on the flat areas, and these by this means have sufficient moisture supply to develop into chernozem, while the rolling areas do not develop the black color. Their subsoils accumulate carbonates, and, should the rainfall come as gentle showers or frequent light rains and were the temperatures in the rainy season lower and the humidity of the air higher, there is little doubt that chernozem would cover both rolling and smooth lands. While, therefore, the heavy rainfall seems to suggest the advisability of placing the western part, at least, of this belt in the belt of chernozem soils, actual soil conditions and other climatic factors seem to justify placing the central part of the gneissic belt in the chestnut-brown belt, while a belt along its western side is placed in the red, i. e.

[39] See, under VII, the table of chemical analyses on p. 219 for the composition of the chestnut-brown soils of this region.

light-colored, soils of the chernozem belt. Maufe describes the areas of black soils in the belt of red soils mainly from the vicinity of Kibigori, Makindu, and Sultan Hamud, all stations on the Uganda Railway, the first near Lake Victoria at its western end, the other two halfway between the lake and the coast. These dark-colored soils are undoubtedly true chernozems, identical with those of the Athi, Kapiti, and Kinango Plains, though the parent rock is gneiss while that of the plains mentioned is volcanic in origin.

CHAPTER VIII

THE SOILS OF ARID AFRICA (SAHARA AND DESERTS OF SOUTHWEST AND NORTHEAST AFRICA)

It seems unnecessary to enter into a description of the desert soils of Africa. Present knowledge as to the characteristics of desert soils and their course and processes of development is based, to no inconsiderable extent, on studies made in the northern Sahara. The descriptive literature, so far as it concerns variations from place to place or details in characteristics, is extremely scant. Such literature as does exist shows the persistence over the deserts of Africa as a whole of soil broadly uniform in the main fundamental characteristics of desert soils. These characteristics include very low humus content and consequently a light color; unleached conditions, with an abundance therefore of carbonates at least in the subsoils; the presence over immense areas of a thick, hard horizon of lime carbonate forming a distinct subsurface crust, or a surface crust when the overlying horizons have been removed; the presence of a crust of other compounds than lime carbonate in many places; the absence of any zone of illuvial accumulation in the soil section, or, in other words, the absence of a subsurface horizon heavier than the soil except in those cases where this is due to geological conditions; the presence in greater abundance than in the other soil zones of excessive salt accumulations, usually known as alkali, and of areas of soils with hardened heavier subsoils due to the influence during the development of the soil of certain deflocculating salts. All these varieties of desert soils probably occur in Africa, but we have no knowledge whatever as to the location and extent of each.

Desert soils are not, as a rule, alkali soils. While areas containing alkali are of more frequent occurrence and larger in deserts

than elsewhere, they do not constitute a large proportion of the desert areas of the world. Alkali accumulates in large quantities, even in deserts, only in spots where drainage waters concentrate.

On the accompanying map (inset, Pl. I) desert soils are represented by two symbols, one showing the brown desert soils of southwest Africa, the outer sides of the Somaliland peninsula, and the northern border of the Sahara, the other showing, without differentiation, the desert soils of the rest of the Sahara. These undifferentiated desert soils as shown on the map are the same as those termed gray desert soils in the introductory soil classification (p. 124).

CHAPTER IX

THE SOILS OF TROPICAL AFRICA (CENTRAL AFRICA AND GUINEA)

What Is Laterite?

The widespread, ever-present redness of the soil in Africa generally, and in equatorial Africa especially, has been noted by all travelers. In most cases the only reference made to these soils by travelers consists in noting their red color.

In 1807 Buchanan[1] applied the name "laterite" to certain red-colored surface material used by the natives of India in building houses on account of the ease with which it could be prepared by cutting the soft or very slightly consolidated moist material into blocks of convenient size and exposing them to the air, where, on drying, they became hard enough to be used as a substitute for brick. From that time until a quarter of a century ago it was the common practice of travelers in the tropics, or in fact in almost any part of Africa, tropical or extra-tropical, to apply the term "laterite" to all soils with a red color and consider the matter ended with that. This was due mainly to the lack of knowledge of the chemical characteristics of these soils as well as to a lack of agreement among scientific men as to the characteristics, physical and chemical, that should be connoted by the term. No detailed studies of the chemistry of this material were made in Buchanan's time or for many years afterwards, the term being applied on the basis of the presence of an amount of a substance, presumably a compound of iron, sufficient to cause a hardening of the soil on exposure to the air. On account of the emphasis on the red color and the use of the material as a substitute for brick, presumably because of its high content of iron, the term was gradually extended to all red surface materials in the tropics, especially

[1] Francis Buchanan: A Journey from Madras through the Countries of Mysore, Canara, and Malabar, etc., 3 vols., London, 1807; reference in Vol. 2, p. 441.

those containing iron segregated in the form of concretions or slaglike masses.

Following the lead of the British geologists in India it became a common practice to separate tropical red soils into two groups, one without the segregated iron oxide and the other with it, differentiated approximately as detrital laterite and residual laterite, i. e., in the latter case, laterite still occupying the place in which it had been developed and, in the former, laterite which had been removed by erosion from the place in which it had been developed and which had been accumulated by deposition in another place. The residual laterite was usually characterized by the presence in the subsoil, or throughout the whole soil profile, of an iron oxide crust—a bed of iron oxide concretions or a slaglike accumulation of such material sometimes constituting the whole soil profile, with fine material occupying the interstitial parts of the mass. In many cases the surface of the soil was covered by fragments of such accumulations, having, in part at least, been exposed at the surface through the activity of erosive forces. It was often stated, in particular cases, that residual laterite constituted true laterite, while detrital laterite was alluvium derived from lateritic rocks.

Through the influence, apparently, of engineers and a few travelers the term became at a later date restricted to the lateritic material in place. This tendency was advanced and made more general through the influence of Wohltmann[2] and other German travelers as well as others. Finally the term was used by many travelers to designate merely the iron oxide accumulations. This meaning was given it by many travelers in Africa during the eighties and nineties of the last century and is still given it by a number of engineers and geologists. Ball and Shaler[3] called attention to the usage still prevailing among Belgian geologists at the time of the publication of their paper and recom-

[2] Ferdinand Wohltmann: Die natürlichen Faktoren der tropischen Agrikultur und die Merkmale ihrer Beurteilung, Leipzig, 1892.

[3] S. H. Ball and M. K. Shaler: Contribution à l'étude de la partie centrale du Congo Belge y compris la région du Kasaï, extrait des *Annales de la Société Géologique de Belgique* (Publications relatives au Congo Belge et aux régions voisines, Année 1912–1913), Liége, 1913, pp. 199–247.

mended its discontinuance. Since the publication of Bauer's[4] work on the Seychelle Islands in 1898 those persons whose work is primarily with soils rather than with geological formations have abandoned this use of the term.

This was the status of the subject when Bauer's epoch-making work was published in 1898, the results of which were still further elaborated in his paper[5] in the volume celebrating the centennial year of the *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie* in 1907. Up to the time of the publication of his first paper the true character, especially the chemical composition, of the products of weathering in the tropics was not known, although the work of the Warth[6] brothers in India and of Berthier[7] in France had produced data enough to cause students to suspect that, in some cases at least, these products were not at all like the ordinary products of weathering developed in cooler climates and to give also some clue as to their probable character.

Bauer's studies consisted of the examination of samples collected by Brauer in the Seychelles showing all stages in the processes of weathering from the unchanged granite, diorite, and sandstone to the final product identified by Brauer as laterite on the basis of its physical characteristics, the only basis of identification hitherto used.

These studies, carried on both with the microscope and in the chemical laboratory, showed that in all these rocks the completely weathered product retained the structure of the parent rock; that the feldspathic and other aluminum silicate minerals in the parent rock, whatever their composition, changed entirely to a mass of colorless flakes showing well-defined polarization

[4] Max Bauer: Beiträge zur Geologie der Seychellen, insbesondere zur Kenntnis des Laterits, *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, 1898, Vol. 2, pp. 163–219. Stuttgart.

[5] Max Bauer: Beitrag zur Kenntnis des Laterits, insbesondere dessen von Madagaskar, *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, Festband zur Feier des 100 jährigen Bestehens, Stuttgart, 1907, pp. 38–90.

[6] H. and F. J. Warth: The Composition of Indian Laterite, *Geol. Mag.*, N. S., Decade IV, Vol. 10, 1903, pp. 154–159.

[7] M. P. Berthier: Examen du fer forgé par les nègres du Fouta Diallon (Haut Sénégal) et des minerais desquels ils les retirent, *Annales des Mines*, Vol. 5, 1820, pp. 129–134. Paris.

under the microscope; that the iron of the iron-bearing minerals became segregated into cracks and cavities with more or less impregnation of the flaky material and that the places formerly occupied by the former minerals were filled to a large extent by dark-colored opaque compounds of iron; that in the flaky mass, mainly that derived from the feldspars, were numerous roundish cavities, often partly or completely filled with yellowish brown to reddish brown iron hydroxide; that the quartz of the parent rock remained in the laterite without having suffered any recognizable change; that no essential difference can be found between the weathered product of granite and that of diorite except the greater amount of iron compounds, presumably iron hydroxide in the latter and the presence of pure quartz in the former; that the essential constituent of the weathered product (laterite) of these islands consisted of the colorless flaky mass and that its formation was essentially independent of the character of the parent rock.

The chemical analyses showed that after the elimination of the quartz grains the laterite consisted, in the case of a derivation from granite, of about 60 per cent of alumina, 9 per cent of iron oxide, and 29 per cent of combined water. In the laterite developed from diorite there were 52 per cent of alumina, 21 per cent of iron oxide, and 27 per cent of combined water. The iron oxide is the variable compound and is best considered like the quartz as an unessential constituent, while the aluminum hydroxide is the essential constituent. The microscope showed that this scaly light-colored aluminum hydroxide exists in a crystalline state, and a study of the possible combinations of alumina and water that will satisfy the requirements of the percentage composition of the material in alumina and water led Bauer to the conclusion that the characteristic mineral present is hydrargillite.

Bauer discussed also the relation of the laterite of the Seychelles to bauxite in the northern hemisphere and concluded that the two materials are essentially identical in all respects except in the impurities present in the laterite.

This was probably the most important contribution to the

knowledge of laterite that had been made up to that time. It will be seen, however, that Bauer's conclusions differ widely, in one or two respects, from those arrived at by Campbell, which will be described below (p. 187). The most important difference lies in the conclusions regarding the successive steps in the development of laterite. Bauer was clearly of the opinion—and his results seem to justify his conclusion—that the rock changed from its undecomposed state into laterite directly without going through any intermediate state represented by the occurrence of a definite mineral material. This conclusion seems to be warranted by his emphasis on the retention of the laterite of the structure of the parent rock. In the next most important contribution to our fundamental knowledge of laterite, that made by Campbell, the author is equally emphatic in stating that a rock cannot change *per saltum* into laterite.

The interest aroused by Bauer's results directed attention again to the character of the products of weathering in the tropics. In 1903 two important papers were published in the *Geological Magazine*,[8] which, among other things, brought out the fact that many of the Indian soils that had long been identified as laterites had essentially similar composition to the products from the Seychelles examined by Bauer. These papers and a number of others published mainly in the *Geological Magazine* by Scrivenor,[9] J. B. Harrison,[10] T. Crook,[11] and others[12] showed that an important part of the material formerly identified without question as laterite did not show the presence, in any significant quantities, and some of it none whatever, of the hydroxides of

[8] H. and F. J. Warth, *op. cit.*

T. H. Holland: On the Constitution, Origin, and Dehydration of Laterite, *Geol. Mag.*, N. S., Decade IV, Vol. 10, 1903, pp. 59–69.

[9] J. B. Scrivenor: The Use of the Word "Laterite," *Geol. Mag.*, N. S., Decade V, Vol. 6, 1909, p. 431; *idem:* Laterite and Bauxite, *ibid.*, Vol. 7, 1910, pp. 382–384.

[10] J. B. Harrison: The Residual Earths of British Guiana Commonly Termed "Laterite," *Geol. Mag.*, N. S., Decade V, Vol. 7, 1910, pp. 439–452, 488–495, and 553–562; *idem:* On the Formation of a Laterite from a Practically Quartz-free Diabase, *ibid.*, N. S., Decade V, Vol. 8, 1911, pp. 120–123 and 353–356.

[11] T. Crook: On the Use of the Term "Laterite," *Geol. Mag.*, N. S., Decade V, Vol. 6, 1909, pp. 524–526.

[12] E.g. Malcolm Maclaren: On the Origin of Certain Laterites, *Geol. Mag.*, N. S., Decade V, Vol. 3, 1906, pp. 536–547.

alumina—these having become more or less definitely accepted as the peculiar constituents of laterite.

The next step had evidently to be a discussion of the results so far published for the purpose of framing a definition in terms of chemical composition. A number of papers were published between 1909 and 1913. The first of the two most comprehensive papers was published by Fermor[13] in 1911 and the second by Lacroix[14] in 1913.

Fermor proposed that the term laterite should be restricted to mixtures of one or more of the oxides of aluminum, iron, titanium, and manganese which are more or less hydrated. Since, however, the composition of many soils hitherto identified as laterite had been shown to consist largely of other compounds than these, it became necessary to define in terms of these compounds the meaning of the term. After full discussion he proposed that the term laterite should be restricted to soils containing from 90 to 100 per cent of the constituents mentioned above, which he designated as lateritic constituents; that soils containing from 50 to 90 per cent of these constituents be designated as siliceous laterites or lithomargic laterites; that those containing from 25 to 50 per cent of these constituents be designated as lateritic lithomarge or lateritic soil; while those with less than 25 per cent should not receive any designation based on the presence of such constituents.

Lacroix differed from Fermor in some of the details of his definition, particularly with reference to the crystalline or uncrystalline state or form of occurrence of the aluminum hydroxide, but agreed with him in the greater part of his classification according to the percentage of hydroxides present.[15]

In each of the three groups into which these products of rock

[13] L. L. Fermor: What is Laterite?, *Geol. Mag.*, N. S., Decade V, Vol. 8, 1911, pp. 454–462, 507–516, and 559–566.

[14] Alfred Lacroix: Les latérites de la Guinée et les produits d'altération qui leur sont associés, *Nouvelles Archives du Muséum d'Histoire Naturelle*, Ser. 5, Vol. 5, 1913, pp. 255–358. Paris.

[15] The greater part of Lacroix's paper dealt with the laterites of French Guinea, so that his reference to the definition of the term in terms of the chemical composition of the soil was only a preliminary part of his discussion.

decomposition from the tropics are divided free quartz may be present. It is usually residual from the free quartz in the parent rock but according to some investigators may be developed in the process of soil formation. Since Fermor's definition is based on the chemical composition of these products and since true laterite is to be held to be material with less than 10 per cent of non-lateritic constituents, it follows that, leaving quartz out of consideration as an impurity, the percentage of combined silica is equally important as a negative factor in the definition of lateritic soil. Fermor suggests that no soil be identified as laterite which contains more than 5 per cent of silica other than quartz. If this be all combined with the alumina, as is usually the case, there would be present a maximum of 10.72 per cent of aluminum silicate.[16]

The latest important contribution, and probably the most important on laterite published since the first paper by Bauer, appeared in 1917 and represents the product up to date of studies carried on through a long series of years and prosecuted in many parts of the tropics by J. Morrow Campbell.[17] The paper is concerned primarily with the processes of laterite development, there being only incidental reference to the geography of laterites. The author makes a definite contribution to our knowledge of laterite and to the processes by which it develops.

The distinct advances made by him beyond any point previously reached relate mainly to the processes of rock decomposition in the tropics. He separates these into two groups, which he designates as *alteration* and *weathering*. The former takes place within the zone of permanent saturation (by water) and consists of the elimination to a greater or less extent of iron and the conversion of alkaline silicates of alumina into hydrous silicate

[16] Since quartz is considered an impurity rather than a real lateritic constituent it follows that the percentage of lateritic constituents in Fermor's groups should apply to the constituents of the soil not including the free quartz. If, for example, a soil contain 60 per cent of lateritic constituents and 40 per cent of quartz it would be a lateritic just the same as if it contained 93 per cent of lateritic constituents and 7 per cent or less of quartz. In the former case the soil would be merely a sandy laterite.

[17] J. M. Campbell: Laterite: Its Origin, Structure, and Minerals, *The Mining Magazine*, Vol. 17, 1917, pp. 67–77, 120–128, 171–179, 220–229. London.

of alumina. This takes place in both tropical and cool climates but proceeds more rapidly in the former than the latter. The result is the formation, in this zone, of a bleached mass of hydrous silicate of alumina. In no case is aluminum hydroxide produced in this zone.

The latter, or the product of the process of true *weathering*, as he defines the term, takes place only within the zone of intermittent saturation (with water)—a zone in the earth's crust lying immediately above the zone of permanent saturation. It is in this zone that the formation of laterite takes place. According to the author, this process cannot operate directly on the parent or unaltered rock, and, when through earth movements the unweathered rock is raised through the zone of permanent saturation too rapidly to become kaolinized as it passes through it, it will not be weathered into laterite even if the crustal movement leave it in the zone of weathering. "Nothing could possibly be more misleading than the idea that a highly evolved laterite comes into existence by the rearrangement, alteration, weathering, or metasomatic replacement of the constituent minerals of a crystalline rock. Laterite does not form *per saltum* from any rock. Highly evolved examples are the result of a prolonged succession of changes, deposition, solution, redeposition, hydration, dehydration, and segregation, repeated many times, so that the ultimate composition may bear no relation whatever to that of the unaltered rock which originally occupied the same actual space, but was determined entirely by external agencies."

Laterite, according to Campbell, therefore, is the product of changes practically peculiar to the tropics acting on material that has previously been changed by the processes identical with those usually operating in temperate and cool climates. In both regions the processes and products are alike up to the point where the original crystalline rock has been altered to hydrous silicate of alumina. Beyond that the processes and products diverge.

As a bed of laterite ages it tends toward the complete hydration of the alumina and the dehydration of the ferric hydrate, usually

also toward the removal of the iron, leaving a pure aluminum hydroxide or bauxite.

While Campbell's important study deals mainly with the processes by which laterite develops, for a definition of laterite and related soils we can do no better than fall back on the studies of Fermor and Lacroix of the chemical composition of these soils. The general classification outlined by them has been more or less definitely accepted. It is the basis for the following definitions.

Since the term "red loams" (*Roterde*, *terra rossa*) has long been in more or less common use among soil students and geologists, that term will be used in the following pages to include those soils in Africa whose composition is supposed to be essentially the same as Fermor's last group, or those containing less than 25 per cent of lateritic constituents. "Laterite" will be used to include those soils whose composition is or is supposed to be the same as Fermor's first group, or those containing from 90 to 100 per cent of lateritic constituents; while all soils with an intermediate composition or those supposed to have such, containing from 25 to 90 per cent of lateritic constituents, will be described as "lateritic red loams."

The definition of the term is placed entirely on a chemical basis, and its identification on the results of laboratory work. Since it is well known that soils may vary widely enough in physical characteristics within the limits of a given chemical composition, or at least a narrow range of composition, to warrant designating the bodies thus differing as different soils, it follows that as soils each of these bodies, with great probability, constitutes a group of soil units rather than a soil individual.

Certain facts, which need not be cited here, indicate that, by and large and taking all laterites throughout the world into consideration, lateritic composition is more often associated with the concentration of iron into concretionary or slaglike masses than with soils free from such bodies. Laterites occur without them, however, and they occur also in other soils than laterites.

On rolling areas where erosion is in progress and is somewhat active thoroughly weathered products are never allowed to ac-

cumulate, and the soil belongs in some intermediate stage of development between freshly disintegrated rock and the completely weathered product. Theoretically, materials representing these stages in development may be found in regions where laterite is the normal product of complete weathering. The results of such analytical work as has been done on the soils of Africa show that such intermediate products are more abundant than is the end product.

A great many analyses would probably show products in many stages of advance toward the end; but, in treating them, not every minute stage in this advance can be given recognition as marking a soil unit. In treating them practically, even with abundant data available, but few stages can be recognized; while in a treatment like the one in hand not more than three stages should be admitted. The first stage should represent the products of weathering in which the formation of aluminum hydroxide and the solution and removal of the silica or the silicates have not begun or have not proceeded further than the accumulation of a very small amount of the hydroxide. Since the accumulation of hydroxide proceeds with the disappearance of the silica, a definition on the basis of the amount of combined silica present is the simplest way of defining or describing the substance. In this case all the silica except the free quartz will be in combination with the alumina, forming clay.

In the following pages an attempt is made, in a very imperfect and inaccurate way to be sure, to locate the areas of red loams, lateritic red loams, and laterites in Africa. The first group includes a typical group and two subgroups, the latter designated as (a) the immature red loam subgroup and (b) the ferruginous red loam subgroup.

General Soil Characteristics in Tropical Africa

That part of Africa bounded on the south by the Zambezi, on the north approximately by the parallel of 8° N., and on the east by the Tanganyika-Nyasa depression is, in soil characteristics, much more uniform than is any other region of the same size in

Africa, except possibly the Sahara. The topography of the region does not vary widely; the temperature is relatively uniform; and the rainfall, while varying widely, varies, however, above a minimum which is too high to promote the development of such soil variations as are found either in East Africa, South Africa, or Mediterranean Africa. The age and lithologic character of the geological formations in different parts of the region vary rather widely, yet the strong influence of the weathering forces seems to have masked in all cases, and obliterated in many, the influence of the character of the parent-rock material on the soil.

These soils are all reddish and are leached to varying degrees but, in all cases, to the extent of being deprived of their carbonates. They are, in general, thoroughly decomposed, and their mineral content is reduced largely to quartz, aluminum silicates, aluminum hydroxides, and hydrated iron oxides, with smaller quantities of titanium, manganese minerals, alkalies, and alkaline earths. The percentage of organic matter is low, excepting in those areas where, on account of poor drainage, organic matter has accumulated. Such areas are extremely small. The predominant soils of the region are typical humid soils, exhibiting, seemingly in marked degree, a well-developed eluvial surface horizon of relatively light texture and a subsurface or subsoil illuvial horizon of relatively heavy texture. Over large areas of Africa within and without the region here under consideration the surface soil is sandy, owing in part to the development of an eluvial surface horizon.

While, from the point of view of soil character, all of this immense area must be considered potential forest land, yet large sections consist either of pure grassland or of very open forest with a heavy cover of grass beneath the trees. Very little information is available as to the effect on the color of the soil of this grass cover, but what information is available shows that it has not resulted in the production of a black or even a very dark brown soil such as has been produced on the treeless humid soils of the United States and apparently of parts of Argentina. A sample of soil collected by Shantz in the Urundi highland from

pure grassland has a color that would be described as brown rather than dark brown. Another sample[18] collected by him between Luenga and Kongolo on the Lualaba has a surface color that would be described as a strong brown but is no darker than can be found in many parts of the humid region of the United States covered with an original stand of timber—no heavier, apparently, than that covering large parts of Central Africa. The relationship of forest cover to potential forest land in Africa is therefore similar to that elsewhere in the world in that not all such land is covered with forest, even counting the cultivated land in potential forest regions as forest land that has been cleared for cultivation. The relatively light color of the soil in the humid region of Africa may be indicative of the short time during which these lands have had a grass cover, just as the prevailing very dark color of the humid prairies of the United States and Argentina is indicative of a long period during which they have been covered with grass. The weight of this fact, however, in so far as Africa is concerned, can be easily overestimated. This is shown by the smallness of the belted areas of black or very dark colored soils in that continent such as the chernozem belt, where the soil is not potential forest land and during the existence of present geographic conditions cannot have been covered with forest. As already explained, the type of rainfall and the prevailing high temperature throughout Africa and other tropical regions have been powerful factors in preventing that accumulation of organic matter that gives to soils a dark color, regardless of the presence of a grass cover, which is the effective cause of such an accumulation in temperate regions of the world.

The Red Loams

The soils of this group, as it is defined in this work, include those red soils of Africa, especially of Central Africa, characterized by an important percentage of combined silica, with or without free quartz; the absence or practical absence of aluminum

[18] Nos. XXI (Urundi) and XIII (Lualaba). For location see, under these numbers, map, Fig. 1, p. ix; for chemical analysis, see table, p. 220.

hydroxides and the combination of the alumina into some form of hydrous aluminum silicate or in its original form in the still undecomposed silicate minerals of the parent rock; the presence of an important percentage of iron in the form of ferric hydroxide, usually with a low percentage of combined water; and the presence of a low but significant percentage of alkalies and alkaline earths and of phosphorus. The term is applied to a soil that has been more thoroughly leached than the soils of the regions heretofore described, or the soils of the temperate zones as a whole, but not so thoroughly leached as those red soils of Central Africa yet to be described. From the chemical point of view and in so far as their value is determined by chemical characteristics, they are the most productive, other things being equal, of the three groups of associated Central African soils.

The intermediate stage of leaching characteristic of the red loams is a feature of the soils of the tropics as well as of the subtropical regions. Red loams may develop in the tropics either where the rainfall is too high for the development of the soils of the chernozem group and yet not high enough for the development of either of the groups of associated soils, or where the soil is not advanced enough in its development to be placed in either group. The young red loams developing under high rainfall are in progress of development to laterite. In subtropical regions the mature soils are characterized by a composition that, so far as degree of leaching is concerned, is marked by a content of alkalies and alkaline earths which warrants placing them in this group, whereas in the highly humid tropics they represent immature soils only.[19]

The accurate determination of the distribution of a group of soils defined, as these are, in terms of chemical composition, can be based only on abundant chemical data. It is a well-known fact, already stated repeatedly, that such data are not available. Of the whole area over which the typical soil of this group is supposed to extend and is shown on the accompanying map (as *Lr* on inset, Pl. I) only a very few samples have been col-

[19] Footnote 19, see bottom of p. 194.

lected and analyzed. These were collected by Shantz, with one exception, from various places in the region and were analyzed by W. O. Robinson, R. S. Holmes, F. A. Barker, and G. J. Hough in the laboratories of the Bureau of Soils.

The composition of these soils is shown in the tables on pages 219–220 under Nos. VIII to XVIII. They are illustrated in Figures 44–49.

After the chemical analyses were completed three samples from the area of the red loams were selected for special examination for the purpose of determining the presence of aluminum hydroxides. One of these samples, No. VIII, was collected from the middle of an ant hill at Elizabethville, Belgian Congo; another, No. XII, from a depth of 42 inches beneath the surface on a bracken-covered area at Elizabethville, and a third, No. XV, from a depth of 36 inches on a slope between Luenga and Kongolo on the Lualaba River. They were subjected to microscopic analysis by W. H. Fry in the laboratories of the Bureau of Soils, with the following results:

No. VIII	contained	41.3	%	of	quartz	in	fractions	larger	than	clay
No. XII	"	31.5	"	"	"	"	"	"	"	"
No. XV	"	73.2	"	"	"	"	"	"	"	"

Robinson discusses the results of the analysis of sample No. VIII as follows:

> This sample contains 41.3 per cent of quartz in fractions larger than clay. Mechanical analysis (made in the laboratories of the Bureau of Soils) shows 39.4 per cent of clay, leaving 60.6 per cent of constituents or fractions larger than clay. Forty-one and three-tenths

[19] The immature soils of the tropics are placed in the red loam group here for convenience of discussion and because of similarity of chemical composition. It is not maintained that they belong in that group genetically. Eichinger (Düngungsversuche in den deutschen Kolonien, Heft 6) designates these as red loams but apparently uses the term mainly as a descriptive one and in order to differentiate them from the laterites of the same region. He does not discuss their relation to the red soils of the southern United States or those of the Mediterranean region, all of which seem to have a chemical character very similar to that of the immature soils of the highly humid tropics.

Lacroix (work cited in footnote 14) shows that in French Guinea the soil from syenite and gabbro does not pass through a red loam stage in its development and that the transition from the fresh parent rock to true laterite is so sharp that it may be studied in the space of a single microscopic slide. He states further that the soils derived from schists in Madagascar pass through a red loam stage into laterites. Attention is called in this connection to the decided divergence of view between Lacroix and J. Morrow Campbell as to the possibility of the development of laterite, *per saltum*, from consolidated rock (see p. 185).

FIG. 44

FIG. 45

FIG. 44—Section of red loam at Moshi, Tanganyika Territory. Uniform deep red color to depth of 10 feet. Vegetation type of locality: temperate forest. April 15, 1920.

FIG. 45—Section of strong red loam at Embu on lower slope of Mount Kenya, Kenya Colony. Vegetation type of locality: temperate forest. May 3, 1920.

FIG. 46

FIG. 47

FIG. 46—Section of red loam, Kalule Sud, Belgian Congo. Surface horizon is gray and subsoil red. Partially weathered rock exposed in lower half of section. Vegetation type of locality: dry forest. Jan. 8, 1920.

FIG. 47—Section of red loam south of Malele between Luenga and Kongolo, Lualaba River, Belgian Congo. Dark reddish brown surface horizon. Bright red with iron concretions at 3 feet and yellowish red at 6 feet, bottom of exposure. Gravel horizon at about 4 feet. (See chemical analyses under XIII–XVII in table on p. 220.) Vegetation type of locality: high grass-low tree savana. Jan. 30, 1920.

FIG. 48—Detail of Fig. 46. Pale red surface horizon extending to about 3 feet from surface; red horizon below.

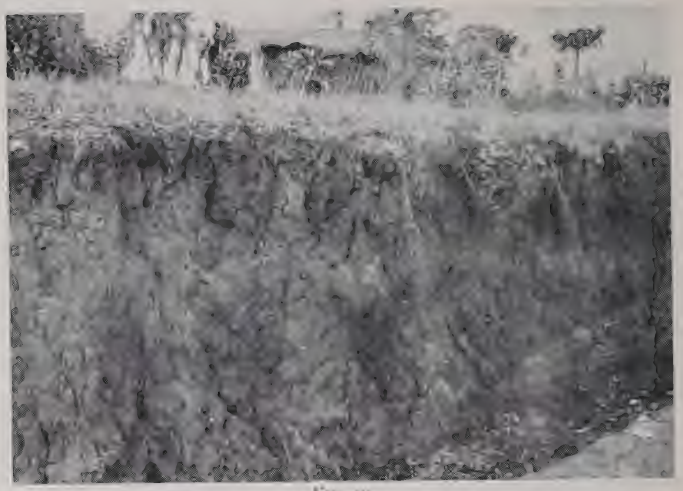

FIG. 49

FIG. 50

FIG. 49—Section of red loam at Port Bell, Uganda. Dark chocolate-red surface horizon with red subsoil. Vegetation type of locality: high grass-low tree savana. July 12, 1920.

FIG. 50—Building blocks, probably lateritic if not laterite, dug out between Mesindi and Butiaba, Uganda. The region is shown as red loam on the soil map (inset, Pl. I), but it probably contains areas of lateritic red loams. Vegetation type of locality: high grass-low tree savana. July 19, 1920.

per cent of 60.6 per cent is 25.03 per cent, which is the percentage of quartz in the whole sample, provided there is no free quartz in the clay group. The percentage of silica in the sample is 64.36 [see table of chemical analyses, p. 219]. When the 25.03 per cent of quartz is subtracted from this there is left 39.33 per cent of combined silica in the fractions larger than clay.

The percentage of alumina present in the sample is 17.16. If this be combined with silica it will require only 20.14 per cent of the combined silica, leaving a surplus of 19.19 per cent. About 7 per cent of silica would be required to satisfy the Fe_2O_3 present, leaving an excess of 12.2 per cent of combined silica or silica in the clay fraction combined or uncombined unaccounted for, strongly suggesting a considerable amount in the clay fraction. There can be no excess of alumina present, therefore, over and above the amount required to take care of the combined silica present, but on the other hand there is enough and to spare of combined silica to take care of all the alumina.

Attacking the matter from another standpoint we get the following results. Chemical analysis shows the presence of 6.32 per cent of combined water. If all the R_2O_3 were present in the form of the hydroxide $R(OH)_3$, 12.3 per cent of combined water would be present. If, however, all the R_2O_3 groups were combined with silica in the form of $R_2O_3.2SiO_2.2H_2O$, 5.8 per cent of combined water would be present. Since the soil is red there must be some free $Fe(OH)_3$ present, or otherwise the soil would not be red, since $Fe_2O_3.2SiO_2.2H_2O$ is not red. This would readily take care of the difference between 6.32 per cent of water and 5.8 per cent. It seems, therefore, that all the Al_2O_3 present is combined with silica and that most of the Fe_2O_3 is present in the form $R(OH)_3$.

The result of an analysis of the figures for the other sample from Elizabethville and the one between Luenga and Kongolo, without giving the course of reasoning in full, is stated by Robinson as follows:

Sample	Total SiO_2	SiO_2 Less Quartz	Excess SiO_2	Excess Al_2O_3	Excess Fe_2O_3	Combined H_2O	Calculated H_2O Present in Hydroxides
No. XII	60.91	29.4	6.8	None	—	6.99	—
No. XV	79.73	6.5	None	1.1	3.9	3.67	2.5

On the basis of these results there seems to be no aluminum hydroxide present in the samples from Elizabethville and very little, if any, in that from the Lualaba between Luenga and Kongolo.

An analysis of a sample from Malanye, Portuguese West Africa, is quoted by Pechuel-Loesche.[20] The sample was collected and described by Buchner and analyzed by Schwager. The soil is clearly not a laterite; and, while no microscopic analysis has been published or probably was ever made and while there are in the literature no data enabling the student to determine what proportion of the silica present is combined, the fact that a low but important percentage of each of the alkalies and alkaline earths is present indicates that leaching has by no means reached the final stage of its operation. The low percentage of combined water and the comparatively high percentage of alumina render it probable that aluminum hydroxides are present in very low percentage, if present at all. These considerations seem to justify the correlation of this soil with the red loam group. The composition of soil is shown in the table on page 220, under No. XVIII.

The method of analysis is not indicated by Pechuel-Loesche, though it is apparent that the fusion method was used, and the percentages represent the relative total quantities of the several constituents present.

This analysis and those made in the laboratories of the Bureau of Soils constitute the sum total of our knowledge of the chemical character of the typical red loams of Africa. A sample collected by Shantz from the alluvial lands of the Kafue, a left tributary of the Zambezi in Northern Rhodesia, has not been analyzed.

The data available are not sufficient in quantity to serve as a basis for the accurate delineation of the area covered by the soils of the group. Resort must be had, therefore, to the distribution of those physical characteristics of Central Africa known

[20] Eduard Pechuel-Loesche: Westafrikanische Laterite, *Ausland*, 1884, pp. 401–407 and 422–428. Stuttgart.

to have predominant influence in determination of soil character, especially the topography and rainfall. This can be done with less confidence in the approximate accuracy of the conclusions than in the case of the distribution of the chernozem and chestnut-brown soil belts. The relation of the latter soils to rainfall, temperature, and topography as well as to geological formations has been well worked out in the temperate and warm-temperate regions of America and Europe, and enough has been done to suggest that the same relations exist in Central America and India. These constitute a series of principles of great value; and, when their application to conditions in Africa is checked by the few, though highly significant, observational and chemical data available, the conclusions seem to be worthy of a considerable degree of confidence.

This is unfortunately not true of the red loams. No studies in other continents have determined the relation of these soils to topographic, geologic, and climatic conditions and forces, nor has the relation of these soils to native vegetation been studied to anything like the extent that has been true of the chernozems. It is well known that these soils in Africa lie between the chernozems on one side and the laterites on the other and nearer the former than the latter, but the "inner boundary" has never been established.

In southern Central Africa there is a large area lying north of the Zambezi and south of the main part of the basin of the Kasai, the main left tributary of the lower Congo, in which the topography seems to lack as a whole the flatness of the interstream uplands of the latter region, in which mountain ranges do not exist, and in which the river valleys as a whole are shallow. The topography is rolling. The temperature is high and relatively uniform, while the rainfall ranges from 32 inches in the southern part to 50 inches in the northern part (see inset map, Pl. II). The amount in the southern part is too high to permit the development of a carbonate zone in the subsoil or the accumulation of a thick surface horizon with a high percentage of saturated organic matter or "humus." Under similar

conditions of rainfall in warm-temperate America the prairies of central Oklahoma and the mesquite-covered plains of central Texas have been developed. The amount of rainfall in the northern part of the red loam belt in Africa is about equal to that of our southernmost Southeastern States, in which the red soils of the southern Piedmont region have been developed. They are characterized by low percentages of the alkalies and alkaline earths and rather high percentages of alumina, but in which the percentages of aluminum hydroxides seem to be small if they are present at all, though no careful studies have yet been made for the especial purpose of determining this matter.

The native vegetation in the southern and largest continuous area of these soils in Africa as well as in Tanganyika Territory consists of open or dry forest with a cover of grass beneath the trees. In the northern areas, especially that north of the Ubangi, the main right tributary of the Congo, in about 4° N., it is savana. In the Niger country it is partly savana and partly dry forest. (See Pl. I.)

The rocks underlying these soils range from gneiss to sandstone; but the broad characteristics of the soil, its chemical composition, and general physical characteristics have been determined to a much greater extent by the climate than by the parent rock. Eichinger [21] has called attention to the wide variation in the character of the rocks of former German East Africa in the vicinity of the Amani agricultural experiment station in the Usambara highlands and contrasted it with the striking uniformity of the soils overlying these rocks, and Niklas [22] states the relationship as a general principle as follows: "When the surface soil is taken into consideration we soon observe that the processes of weathering lead to an obliteration of the sharp differences between the original or parent materials." If this statement be true of a region like Germany it would be legitimate to conclude that it is equally true, as to degree, in a region like tropical Africa and that it is applicable not to the surface

[21] Düngungsversuche in den deutschen Kolonien, Heft 6, Berlin, 1920, p. 30.
[22] Hans Niklas: Erläuterungen zur geologischen Karte des Königreichs Bayern, Blatt Ampfing (No. 676), p. 33.

soil only but to the subsoil as well. Feldspathic and shale rocks would undoubtedly produce a heavy soil which no amount or character of weathering could make sandy, and a rock made up of quartz grains could not form anything but a sand; but these extremes in rock character seem to be rare in Africa. The surface soils over wide areas are sandy, but this seems to be the case in regions where the parent rock is gneiss and equally so where it is sandstone. In both cases the surface soil, like that of our own Southern States, seems to be invariably lighter in texture than the subsoil—a characteristic due to the action of a moderate to rather high rainfall.

The largest area of typical red loams lies in the extreme southern part of the Belgian Congo and the northern part of Northern Rhodesia. A considerable area lies in Portuguese West Africa, and a smaller one in Tanganyika Territory. Other areas, all of small size, are found in the Cameroons and adjacent portions of Nigeria; and many small areas are included in some of the other types. (For distribution of typical red loams see *Lr* on inset map, Pl. I.)

These soils as a whole cannot be said to be highly productive. They seem to resemble our own red soils developed under the relatively high rainfall conditions that exist in North and South Carolina, Georgia and Alabama. The agriculture of the region suffers, however, the disadvantage of seasonal distribution of rainfall. This makes the growing of crops in the dry season difficult. With sufficient moisture properly distributed these soils should be considered as moderately productive.

Ferruginous Red Loams

The ferruginous red loams seem to range in color from gray through brown to red. The group includes those widespread African soils, apparently abundant throughout that part of the continent lying south of the Sahara where the rainfall is moderately high, occurring on flat lands and in shallow basins. It is the soil designated almost universally by the older group of

scientific travelers in Africa as laterite. By many of these travelers the term was applied only to ferruginous concretions and crusts occurring mainly in the subsoil, and by a few geologists it has been so designated up to a few years ago. The term red loam is applied to them because they seem more often to be reddish than any other color and because they occupy positions intermediate, geographically and climatically, between the typical red loams and the laterites. Nothing is known of their chemical composition. The literature does not appear to contain a complete analysis of this soil from any locality. It is probable that the composition varies rather widely from place to place and that when this has been determined the soils here treated as a single group will be found to consist of more than one group, probably ranging from laterite to red loam or even to soils still richer in their content of alkalies than the red loams. They are treated as a unit in this study because of the presence in the subsoil of a zone of ferruginous accumulations in the form of separate concretions, of a ferruginous network, or of a crust of iron oxide more or less continuous. The zone varies in thickness from a few inches to several feet and may reach to the surface either through the upward growth of the accumulating concretionary mass or through the erosion of the overlying soil horizons, exposing the crust at the surface. The zone may pass laterally into grits, into ferruginous conglomerates and breccias, and into ferruginous clays.[23] In French Guinea it is designated by Lacroix[24] as *cuirasse ferrugineuse* and as *conglomérat ferrugineux* by Chautard.[25]

Chautard describes it as the product of the final stage in the process of laterization, though he quotes no analyses. It is in this region associated with true laterites and the finer parts of the material, and such soil as may overlie the iron crust is in all probability lateritic in composition. In this region it seems to differ in that respect from the soil in the Kasai basin.

[23] Ball and Shaler, work cited in footnote 3.

[24] Alfred Lacroix, work cited in footnote 14.

[25] Jean Chautard: Étude géophysique et géologique sur le Fouta-Djallon (Guinée et Soudan français), Paris, 1905.

Ball and Shaler do not describe a profile of this soil of which the iron crust is merely the lower part. They state that it rests on permeable beds, the latter lying on impermeable beds within a few feet. The South African geologists state that it overlies impermeable beds in some places and elsewhere occurs in swamps, but in the latter case it is not made clear whether it does or does not overlie impermeable beds. Arsandaux [26] does not mention the occurrence in French Guinea of any impermeable horizon underlying the ferruginous crust.

It is apparent that two or more widely different soils are here included in one group. Ball and Shaler [27] describe the soil in the Kasai region as a feature confined to the level savana plateaus, implying that the development of the ironstone horizon is due to imperfect drainage and that it is developed essentially like a bog iron ore. The same explanation of its origin is implied if not actually stated by Mennel [28] in many of its occurrences in Rhodesia. He states that the iron crust, designated by him as laterite, occurs under the soil only in flat places and swamps. Hatch and Corstorphine [29] describe such crusts as laterite and explain their formation as an accumulation taking place in pools of stagnant water during evaporation.

In none of these cases is any information given as to the chemical composition of the soil overlying the iron crust. In Rhodesia the occurrences lie in a belt with low rainfall, associated with dark-colored heavy surface soils and carbonate-bearing subsoils. Presumably they are not strongly leached and must be regarded, in the absence of direct evidence to the contrary, as flat-land phases of such soils as the prairie loams of the Transvaal. That the Transvaal prairie is underlain in places with such a crust is shown by Passarge and by samples collected by

[26] H. Arsandaux: Contribution a l'étude de l'altération des roches silicatées alumineuses dans les régions intertropicales, *Bull. Soc. Française de Minéralogie*, Vol. 36, 1913, pp. 70–110. Paris.

[27] Work cited in footnote 3.

[28] F. P. Mennel: Notes on Rhodesian Laterite, *Geol. Mag.*, N. S., Decade V, Vol. 6, 1909, pp. 350–352.

[29] F. H. Hatch and G. S. Corstorphine: The Geology of South Africa, London, 1905, pp. 265–267.

Shantz. Passarge[30] describes a profile exposed near Belfast, 115 miles east of Pretoria, which consists of a surface sod, underlain by one to one and a half feet of gray sand and this in turn and abruptly by a zone of slaglike cellular "laterite." The latter is nothing more than the crust of accumulated iron oxide. He says such a crust underlies wide areas in the Transvaal, mentioning especially a thick crust seen in the Middelburg district, between Belfast and Pretoria.

Shantz collected a sample at Vereeniging, Transvaal, consisting of a dark-brown surface horizon, a reddish brown upper subsoil and a horizon of yellowish concretions at about four feet. The occurrences in French Guinea of the iron crust or of the soil underlain by it, so well described by Chautard, Arsandaux, and Lacroix,[31] lie in a region of heavy rainfall and in association with true laterite, though it is not clear that any chemical analysis published by them covers the soil underlain by the iron crust. There can be very little doubt, however, about the lateritic nature of the fine material inclosed in the crust or of such soil as may overlie it. As elsewhere it is confined to flat lands.

It seems evident, therefore, that the soils of Africa underlain by an iron crust range in character from the practically unleached associates of the chernozems of the Transvaal through those of the moderately leached prairie loams of that province and the more thoroughly leached red loams and lateritic red loams of the Belgian Congo and the French Congo to those of the laterites of French Guinea. They are not a unit, therefore, in chemical composition. They are alike in their universal occurrence on flat lands and in low places covered with water during the rainy season and in their always having an iron oxide crust in the subsoil or at the surface. It is not apparent that the origin of the crust is in all cases the same. In regions of the lowest rainfall with which the crust is associated it seems to occur only in low places. In regions of very high rainfall, while it is still confined

[30] Siegfried Passarge: Über seine Reisen in Transvaal, *Verhandl. Gesell. fur Erdkunde zu Berlin*, Vol. 23, 1896, pp. 492–507.

[31] Works cited above respectively in footnotes 25, 26, and 14.

to flat topography, it is not clear that its accumulation is due to poor drainage.

So far as our present knowledge is concerned this soil occurs most extensively and in the largest unbroken areas in the southern part of the Belgian Congo. An attempt has been made to differentiate it as a phase of the red loams on the accompanying map (*Lf* on inset, Pl. I) on the basis of the description by Ball and Shaler[32] of its occurrence in the Kasai region. According to them it covers the smooth upland savana regions of the whole Kasai basin, but it is not confined entirely to the savanas. They describe its occurrence in the Congo forest on the watershed ridges between the Aruwimi and the upper Rubi, right tributaries of the Congo in about 1° and 3° N. respectively, and in the plains of the Manyema region, which lies between the upper Congo River and Lake Tanganyika in about 4° S. According to these two investigators the accumulation of the iron oxide in the forest consists of small concretions mainly, while in the savanas it has accumulated into a thick bed which on exposure breaks up into large blocks. No comparison of the topography of the forest with that of the savana region is drawn by them, nor do they discuss the drainage of the one region as compared with the other. We have no basis of fact, therefore, for explaining the different character of the crust in the two regions. In the main part of their paper they state that the crust is confined to the savanas but in a footnote explain that since the paper was written the crust has been identified in the forest. Presumably it has a relatively limited distribution in the latter region, and when it occurs at all the crust may be considered imperfectly developed. In the accompanying map, therefore, it is placed on the watershed ridges of the eastern Congo and in the Aruwimi-Rubi region. Dr. J. Bequaert, chief entomologist of the Belgian Congo, reports[33] the occurrence of laterite in the high plateaus of the northern part of the Tanganyika-Congo watershed. No analyses have been made, so that the identification is based on

[32] Work cited in footnote 3, p. 182.
[33] In private conversation.

field inspection only. The rainfall, so far as it is known, seems rather low (around 40 inches; see inset map, Pl. II) for the development of laterite; and so, in the absence of chemical data, the soils are included in the red loams with iron crust.

Chevalier[34] described the region between the Ubangi and the village of Ndele, which lies approximately in 9° N. and 21° E., as a high plateau dissected with valleys, apparently broad. The remnants of the plateau are capped with a "*conglomérat ferrugineux*" which does not extend into the valleys nor north of the, presumably, east-west escarpment marking the northern edge of the high plateau lying immediately south of Ndele.

Guillemain [35] discusses the soils of a part of the Cameroons but states that primary laterite, a designation used by him for a soil underlain by an iron crust but with no reference to its chemical composition, occurs very sparingly in the region traversed by him—the coastal lowland and the highland region of the western and northwestern parts of the colony. Such areas as he saw were confined to the coastal lowland, but he states that such a soil probably occurs in the plateau region of the central Cameroons. No reference to such occurrence in this region has been found; but on the basis of all the factors, topographic and climatic, it seems probable that it is present. No attempt has been made on the accompanying map to show its distribution on the coastal lowland on account of the small areas involved.

Ferruginous red loams are also shown on the accompanying map in the lowlands of the Benue River in eastern Nigeria, but no mention of their actual occurrence has been found in the literature. The mapping is based wholly on the topographic and prevailing climatic conditions. Lamb [36] describes the road from Kano east to Maiduguri (near Dikoa in the Chad depres-

[34] Auguste Chevalier: Rapport sur une mission scientifique et économique au Chari-lac Tchad, *Nouvelles Archives des Missions Sci. et Litt.* Vol. 13, Paris, 1905. pp. 7–52; reference on p. 12.

[35] C. Guillemain: Beiträge zur Geologie von Kamerun, *Abhandl. Kgl. Preussischen Geol. Landesanstalt*, N. S., No. 62, Berlin, 1909.

[36] P. H. Lamb: Notes on a Visit to Lake Chad, *Geogr. Journ.*, Vol. 58, 1921, pp. 443–446; reference on p. 443.

sion) as being surfaced with "laterite," evidently using the term to designate the iron crust or iron concretions.

The occurrence of the iron crust and its association with laterite in French Guinea has been already referred to.

Summing up the situation, therefore, it may be said that soils with iron crust in the subsoil or on the surface are widely distributed in Africa south of the Sahara. They are confined in occurrence to smooth surfaces, either flat or gently sloping. The evidence is not clear that they occur in regions of uneven topography, even though it be no rougher than what is designated as rolling in America, though the presumption is against occurrence in such situations. They occur also beneath swamps or depressions filled with water during the rainy season and presumably dry during the dry season. They occur in regions in which the rainfall varies greatly, ranging from less than 20 inches in the Transvaal through 50 to 60 inches in the Kasai basin and the Ubangi-Shari region to 70 inches or more in the Futa Jallon upland in French Guinea. The soil varies in chemical character, if that may be estimated on the basis of the rainfall to which the soil has been long subjected, from the faintly leached condition characteristic of the chernozems through that of the red loams to that of the laterites. These various soils, grouped under the heading of ferruginous red loams and shown on the map as a unit are a unit only as regards the presence of the iron oxide crust. In other respects they seem to vary within rather wide limits. Only the larger areas of these soils are shown on the map.

These soils are not as a rule highly productive, though if the iron crust lie three feet or more below the surface they cannot be considered unproductive merely on account of its presence. They constitute the surface soil in the savana region of the southern Congo and of the Ubangi-Shari country and seem to support a relatively thin population but afford pasturage to great numbers of cattle.

Immature Red Loams

The term immature is applied to these soils mainly to meet the requirements of a short designation. It is thought, how-

ever, that the soils mapped in this group (*Li* on inset, Pl. I) may, with scientific justification, be so designated because of their characteristics as soils. They occur on the mountain and hill slopes throughout Central Africa. They are made up of material of relatively recent disintegration from the parent rock, the soils in such positions being kept permanently fresh or young through erosion, soil creep, and landslides, which carry away the soil before it has existed as such long enough to become leached or before any compaction or hardening of the subsoil has taken place. They are "rejuvenated" so rapidly that at no time do they exhibit the features of the mature soil profile characteristic of the prevailing climatic conditions of the locality. The profile approaches in uniformity and in the absence of well-developed soil horizons the profile of freshly laid alluvium. In these respects they may be said to be both physically and chemically immature as soils, since they are leached to a relatively slight extent and are marked by the absence of well-developed soil horizons.

It is well within the limits of possibility that a soil on a relatively steep mountain slope may be subjected to climatic influences so powerful that it may become thoroughly leached and converted to laterite before it can be removed by erosion. Indeed, it has been shown by Lemoine and Chautard [37] and confirmed by Lacroix[38] that certain rocks under favorable conditions may decompose directly to laterite[39] without passing through any intermediate stage and that in such cases any soil that is present is laterite and not red loam. This is not the usual case, however; and, as analyses by Arsandaux,[40] Hébert,[41] and Lemoine[42] show, these soils may contain relatively high percentages of alkalies and alkaline earths and percentages of com-

[37] Paul Lemoine and Jean Chautard: Sur le phénomène de latérisation, *Bull. Soc. Géol. de France*, Ser. 4, Vol. 8, 1908, pp. 35–38. Paris.

[38] Work cited above in footnote 14, p. 186.

[39] See p. 184.

[40] H. Arsandaux: Contribution à l'étude des latérites, *Comptes Rendus de l'Acad. des Sci.* [*de Paris*], Vol. 149, 1909, pp. 683–685.

[41] Alex. Hébert: Sur la composition des terres de la Guinée française, *Comptes Rendus de l'Acad. des Sci.* [*de Paris*], Vol. 143, 1906, pp. 64–66.

[42] Paul Lemoine and Jean Chautard, work cited in footnote 37.

bined water too low for the presence of hydroxides in recognizable amounts.

These soils have been mapped in relatively few localities, though they must be present in small areas all over the humid region of Africa. The eastern slopes of the East African plateau in the Tanganyika Territory seem to be covered with a fresh soil which, to the west of Mahenge, is rather densely populated and extensively cultivated, notwithstanding the steepness of the slopes.[43] This area has therefore been shown as immature red loam on the map. The same soil occurs in the Usambara highlands [44] and on the slopes of the volcanic peaks in the British territories as well as on those of the Rift Valley; but these areas cannot be shown on the map because they are too small. In the French Congo and the Cameroons it seems to cover the hilly regions along the large streams and the western slope of the interior plateau (not shown). It occurs also on the rugged highlands of the Cameroons (shown) and locally on the hill slopes of the Abyssinian plateau (not shown). It is present on the eastern scarp border of the South African plateau in Natal, the Transvaal, and probably in Rhodesia. It has not been shown on our map in South Africa because no description of the topography, the agriculture, or the chemical composition of the soils of the belt has been found. The topographic, geologic, and climatic conditions, however, are favorable to its occurrence.

The surprising intensity of the native utilization of these soils around the northern end of Lake Nyasa and on the eastern slope of the plateau in the Tanganyika Territory in spite of the steepness of the slopes is presumably due in part to the freshness of the soil, its good water-holding capacity caused by the absence of compaction in the subsoils, and its rather favorable chemical composition; but other factors probably contribute their influences, and these may be stronger than those of the

[43] Hans Meyer: Das deutsche Kolonialreich: Eine Länderkunde der deutschen Schutzgebiete, 2 vols., Leipzig and Vienna, 1909–1910; reference in Vol. 1, p. 336.

[44] Ferdinand Wohltmann and V. Lommel: Chemische Untersuchungen einiger Böden aus dem Hinterlande von Tanga, *Bericht über Land- und Forstwirtschaft in Deutsch-Ostafrika*, Vol. 1, 1902, pp. 182–194 and 335–340. Heidelberg.

soil. The raids of the cattle-raising tribes on the less warlike agricultural tribes, driving the latter into the mountains for protection, has probably been a factor of no little importance in the matter. Another factor to be recognized is the abundant rainfall on these mountain sides.

Lateritic Red Loams

The lateritic red loams from the chemical point of view stand between the red loams on the one hand and the true laterites on the other, the red loams as defined in this paper carrying no free aluminum hydroxide, whereas laterite is made up mainly of it or at least 90 per cent of its alumina is entirely in the hydroxide form and its silica in the form of quartz.

In the lateritic red loams the alumina is in part combined with silica and in part is present in the form of hydroxide. This relationship is based on the assumption, in accordance with the work of Arsandaux and of Lacroix,[45] that in the decomposition of complex quartz-bearing rocks under high rainfall in the tropics the alumina does not pass at once into the hydroxide form without passing through an intermediate stage as a hydrous silicate. Lacroix states that the alteration of mica schist, gneiss, and granite does not take place in such a way as to produce a hydroxide at once, but is progressive. The micas, for example, are progressively deprived of their alkalies and take up gradually an increasing amount of water. Kaolinite or silicate of alumina is produced, mixed with a quantity of aluminum hydroxide, which becomes progressively larger, until the whole mass finally passes into laterite.

The fact having been established with regard to schists, gneisses, and granites that the gradual change from the parent mineral through silicate of aluminum to aluminum hydroxide does not take place warrants the conclusion that other complex rocks, sedimentary or crystalline, decompose in the same way; though Lacroix has shown that, in the decomposition of syenites and gabbros, aluminum hydroxide is formed without

[45] Works cited above in footnotes 26, p. 201, and 14, p. 186, respectively.

passing through the aluminum silicate stage, while Lemoine and Chautard[46] announced this course of development to be universally applicable. The broader work of Lacroix showed this latter conclusion to be untenable.

In rocks more or less permeable to water the hydration of a surface coating of the minerals would cause a disintegration of the rock and the formation of a soil which in its early stages of development would contain considerable percentages of undecomposed minerals, even if in the hydration the product passed at once into hydroxide form. Such a soil would have a considerable percentage of combined silicate. Part of its alumina would be in combination with the silica; and the percentages of alkalies and alkaline earths would remain important, if not high, long after a well-developed soil had been produced. Such a soil would show the presence of hydroxides; but its silica could not be accounted for as quartz, and its alkalies would be too high for laterite.

Such soils seem to have a limited distribution in Africa. Their occurrence has been demonstrated or shown to be highly probable in two places. Shantz collected a sample of soil from the grasslands of the Urundi highland[47] which contains a high percentage of alumina and of combined water with such a relation to each other as to make it difficult to account for them except through the presence of an important percentage of hydroxide. The percentage of alkalies is, however, not extremely low, so that the presence of other minerals than hydroxides is strongly indicated. No examination of the material with the microscope has been made; and so it is not possible to determine the amount of quartz present as well as that of combined silica. As a whole the figures point strongly to the presence of hydroxides but not to their exclusive presence. The existing short-period records[48] indicate an annual rainfall of about 40 inches

[46] Work cited above in footnote 37, p. 206.

[47] See, under XXI and XXII, table of chemical analyses, p. 220; also discussion and analysis in *Geogr. Rev.*, Vol. 12, 1922, pp. 334–335.

[48] Heinrich Schnee, edit.: Deutsches Kolonial-Lexikon, 3 vols., Leipzig, 1920; reference in Vol. 3, p. 587. See also p. 334 in H. L. Shantz: Urundi, Territory and People, *Geogr. Rev.*, Vol. 12, 1922, pp. 328–357.

in this region (see inset map, Pl. II). This sample was collected on a ridge top or near the top and presumably would contain a maximum amount of the products of complete decomposition. The country is strongly rolling, so that by far the greater part of it, the slopes, would be covered by soils less thoroughly decomposed than that of the ridge tops. While the whole area is shown on the accompanying map (inset, Pl. I) as lateritic red loam, it is extremely probable, almost certain in fact, that the larger part of the area is covered by true red loams.

The other locality in which the occurrence of lateritic red loams is indicated by definite data is the Usambara highland in the northeastern corner of Tanganyika Territory. An analysis of an Usambara soil sample made in Wohltmann's agrogeological institute at the Agricultural Academy at Bonn-Poppelsdorf, quoted by Koert[49] showed high percentages of alumina and combined water. The percentages of alkalies and alkaline earths are low but important. This soil has been developed under a rainfall of about 60 inches, an amount large enough when combined with equatorial temperatures to cause a rapid development of hydroxides in the process of rock decomposition. The analysis is, unfortunately, an acid-soluble one, and its results cannot be accepted at full value for the objects here sought; but they may have suggestive value. The analysis is not quoted in the present work.

Arsandaux[50] made some careful studies of samples collected from French West Africa and from French Equatorial Africa. The samples vary considerably in the relative proportions of aluminum silicates and aluminum hydroxides present, but in every case there is present a significant proportion of aluminum silicates, showing that the final laterite stage has not yet been reached in their decomposition. The highest percentage of alkaline silicates present in the whole series was not worked out,

[49] W. Koert: Geologisch-agronomische Untersuchung der Umgegend von Amani in Ostusambara, *Berichte über Land- und Forstwirtschaft in Deutsch-Ostafrika*, Vol. 2, 1904, pp. 143–164. Heidelberg.

[50] Work cited in footnote 26, p. 201.

but in one set of apparently typical samples from the Bambuk region of eastern Senegal the highest percentage was 67, so that the percentage of aluminum hydroxides cannot be high enough to place any of the samples among the typical laterites as they are defined below.

In the Gabon district of French Equatorial Africa, the region from which some of these samples were collected, the rainfall ranges from 60 to 90 inches (inset map, Pl. II). This is higher than the amount on the Urundi highlands. In the Gabon district the topography is rough on account of the thorough dissection of the region. This condition alone would prevent the development of a soil thoroughly reduced to the final stage of hydroxide development. If the topography were such, however, that the products of weathering were left in place for a long period, the development of laterite would seem to be inevitable. A little farther north laterite has been shown on the accompanying map on the smooth coastal lowland of the Cameroons solely on the basis of the smooth surface and high rainfall. In the Gabon district, however, the soils in the area shown on the map as lateritic red loams range, in all probability, from true laterite in the areas of smooth topography through lateritic red loams to red loams not differing in any essential respect from the soils shown as immature red loams along the steep slopes between the high plateau of the Tanganyika Territory and the coastal lowland of the same region.

In Senegal the topography is smoother, but the rainfall is lower; so that conditions for the development of lateritic red loams seem to be present, although the iron crust, considered by Arsandaux as a characteristic marking the final stage of lateritic development, is usually present.[51] His analyses, however,

[51] Arsandaux defines all these soils as laterites, placing in that group, apparently, all soils containing any significant amount of hydroxide of alumina. He would include in his laterite group all the soils here defined as lateritic red loams. Lateritic red loams as defined in this study would comprise all of Lacroix's "siliceous laterites" and most if not all of his "lateritic clay" (see Lacroix, work cited in footnote 14.) It would include Fermor's groups of siliceous laterites or lateritoids and lateritic rocks, including lateritic lithomarge, and probably his quartzitic laterites (see Fermor, work cited in footnote 13).

show the presence of an important percentage of aluminum silicates, but a lower percentage in the surface soil than in the subsoil. Arsandaux's analytical results, on account of their complexity—there are several stages, each employing a different treatment—are not quoted here. The method of analysis is a modification of the acid-soluble method.

The work of J. Morrow Campbell[52] was not seen until after the discussion of the supposed distribution of laterite had been written. Campbell does not attempt to describe the distribution of laterite in Africa or even mention the parts of the continent in which he had identified it. He implies, however, in certain incidental references, a considerably wider distribution than has been given it in the present work. He even identifies it in Nigeria in a region where the rainfall is not more than 30 inches. In the present discussion it has not been assumed that that amount would be sufficient, even in the tropics, to cause the development of laterite. In partial recognition of Campbell's work, however, a belt of lateritic red loams has, on the soil map (inset, Pl. I) been pushed farther northward in Nigeria than anywhere else—so far north that it has absorbed the tropical prairie belt for some distance on both sides of the Niger. A mere glance at the map and a comparison with the rainfall map (inset, Pl. II) will show how illogical this distribution is. If lateritic red loams extend northward to Nigeria as far as they have thus been shown to extend, there seems to be no reason known at the present time for not extending them northward equally far in the region west of this, obliterating completely the western part of the zone of tropical prairie soils. On the other hand the density of population in this latter region seems to indicate a soil somewhat more productive than lateritic red loams are supposed to be. The matter cannot be settled with the data available, and the map must stand as originally drawn, except that part covering Nigeria on the western bank of the Niger, until more definite information can be had.

[52] Work cited in footnote 17, p. 187.

On the basis of the results of Arsandaux's work in the Gabon district and in Senegal and, as just stated, Campbell's work in Nigeria a belt of lateritic red loams is shown on the map extending along the coastal hill belt of the Gabon and the Cameroons and spreading out over the whole lower Niger basin to its western limit in the north-south stretching Togo highlands. Another area shown is in the highlands of the Cameroons, the basis being the probable rainfall.

These are the only localities in Africa from which definite data have been obtained showing a strong probability of the occurrence of lateritic red loams. On the basis, however, of the occurrence of areas of high rainfall this group of soils has been shown on the map in other places. Several localities in the Lake Nyasa region seem to have a rainfall high enough to make the development of hydroxides practically certain (see inset map, Pl. II). Their accumulation is equally certain unless the local topography is such that erosion removes them as rapidly as formed. This seems improbable on the basis of the existing knowledge. Small areas are shown, therefore, in these localities: one on the plateau west of Lake Nyasa, and the other on the lower slopes of the Mt. Mlanji massif east of Blantyre. It is not improbable that considerable areas occur in the highlands of Abyssinia, although, since no knowledge of such occurrence is available, none have been shown on the map.

The soils of the great Congo forest are shown on the map as lateritic red loams. This is done on the basis of the rainfall to which they are subjected and under the influence of which they have been developed. The literature on the region seems to contain no analytical results sufficiently full to warrant a conclusion as to the character of the soils. The publications of the various experiment stations established in the region contain many partial analyses, in which only those portions of the substances reported as soluble in hydrochloric acid were determined. The area has been extended northward beyond the region of the forest so as to cover approximately the area having a rainfall of 60 inches or more. It is sincerely to be hoped that our knowledge

of the real character of the soils of this immense area may not long remain so wholly lacking.

Laterite

As has already been stated in the previous discussion of the history of the development of ideas regarding the nature of laterite (pp. 181–188), the early explorers identified all the red soils of Africa (and most of the soils in equatorial Africa are red) as laterites. It became more or less accepted as a truth that the red soils throughout tropical regions in general were laterites; and, when Bauer's results were published and the products described by him were assumed to be identical with the "laterites" so widely distributed over the tropics, a more or less well-defined opinion spread among soil students that tropical soils are poor to the extent at least that they have been leached of their plant-food elements (alkalies and alkaline earths and phosphorus). When a few years had passed, however, and some actual results of investigation had accumulated, it soon became evident that laterites, in their newly acquired meaning, are not so universally developed in the tropics as had been thought. As early as 1909 Crook[53] stated that "the development of true laterites even in the tropics appears to be much more limited than is usually supposed."

It is apparent from the data available that true laterite has a restricted distribution in Africa. Further studies may show a much wider distribution than now seems apparent. For example, we know nothing, as has been already stated, about the chemical composition of the soils in the Congo basin. On the basis of the rainfall it seems improbable that true laterites are present in large areas in that basin; but such an indirect way of approach, to be sure, as through the rainfall alone has very decided limitations. While much of the map accompanying this paper is based on the rainfall, yet it should be emphasized

[53] T. Crook: Remarks (pp. 449–451) on a Paper by J. M. Campbell, "The Origin of Laterite," *Trans., Instn. of Mining and Metallurgy*, Vol. 19, 1909–10, pp. 432–457. London.

that no delusions are entertained regarding the method. It has been adopted as a last resort and merely as a basis for suggesting certain possibilities and for calling attention to the great lack of direct knowledge of soil conditions on the continent in the hope that the information may be given to the world by those now on the ground.

The two areas from which we have rather satisfactory data regarding the occurrence of true laterites are the Usambara region of the Tanganyika Territory and French West Africa.

The data for the Usambara region consist of analyses published by Koert,[54] to which reference has been already made (p. 210). Since these analyses report merely the composition of the concretions taken from the soil rather than of the whole soil including the concretions, they are not as conclusive as might be desired; yet the result is accepted as expressing the composition of the soil. This is justified by the description of the soil and by certain results obtained by the application of the acid-soluble methods of analysis. The composition of one sample of concretions is shown under XXIX in the table on page 221.

While it seems certain that laterite occurs in this region, the data do not enable us to determine its distribution. Koert states that this soil is confined largely to the ridge tops in places where erosion, land slips, and soil creep have not removed the soil as rapidly as it became leached, and caused the formation of a fresh soil in place of the old one. The rainfall at Amani, the locality of the German agricultural experiment station where the samples were collected, is about 75 inches; but, since this lies in the foothills of the Usambara highland, the amount must vary greatly from place to place according to elevation and exposure. Even a higher, or much higher, rainfall would not necessarily assure the presence of laterite, since its development is dependent on the topography as well as on the rainfall. It has been assumed, however, that the soil is present on the smooth areas throughout that part of Usambara having a high rainfall. Since no details can be shown on the scale adopted,

[54] Work cited in footnote 49, p. 210.

and since no detailed knowledge is available, on the accompanying map (inset, Pl. I) a nucleus of laterites has been shown at the top of the highland. Another nucleus has been shown on the Kilimanjaro massif. The analyses of the Agricultural Academy at Bonn-Poppelsdorf,[55] although covering a wide area of country in what is now Tanganyika Territory, were all carried out by the acid-soluble method, and the results are practically worthless for the objects sought in this paper.

A great deal of good work has been done by French geologists in the study of the soils of French Guinea. The work of Arsandaux has already been referred to.[56] The most important results of chemical studies of soils from this region, results giving more complete chemical information, have been published by Lemoine and Chautard.[57] The samples seem to have been collected along the railway line between the port of Konakry and the top of the Futa Jallon upland. Although the authors of the paper do not publish the results of exhaustive studies of these analyses, yet the low percentage of silica, the high percentages of alumina and iron, the high loss on ignition, and the low percentages of alkalies all unite in fulfilling the requirements of fully developed laterite.

The work of Arsandaux did not show conclusively, or at least the evidence did not show so conclusively as does that of the analyses given by Lemoine and Chautard, the presence of fully developed laterite.

Lacroix[58] does not publish the results of any analyses, but his descriptions show conclusively the presence of laterite in the region between Konakry and the Futa Jallon.

It seems probable that the Atlantic slope of French Guinea, Sierra Leone, Liberia, and part of the Gold Coast includes the largest area of well-developed or true laterite in Africa.

The region is subjected to a very high rainfall—the highest

[55] Ferdinand Wohltmann: Die Ergebnisse der chemischen Untersuchung deutsch-ostafrikanischer Böden, *Tropenpflanzer*, Vol. 1, 1897, pp. 128–133. Berlin.
[56] Above, footnote 26, p. 201.
[57] Work cited above in footnote 37, p. 206.
[58] Work cited in footnote 14, p. 186.

of all areas on the continent of equal size (see inset map, Pl. II)—while the temperature conditions are favorable. The topography is not smooth, but, in spite of that, the data published by Lemoine and Chautard show that laterites are present. They show that throughout that part of the belt traversed by them, underlain by syenite, diabase, and gabbro, the first and only soil formed from these rocks is laterite. They show that the laterite rests on the practically unchanged rock with no intermediate layer of disintegrated but not thoroughly laterized soil.

TABLE OF CHEMICAL ANALYSES OF AFRICAN SOILS
(For description of samples and localities at which they were collected, see below and map, Fig. 1)

	I	II	III	IV	V	VI
SiO_2 (silica)	53.54	40.97	48.72	49.15	40.54	63.36
TiO_2 (titanium oxide)	—	0.38	1.72	1.18	3.62	1.18
Fe_2O_3 (ferric oxide)	9.75	4.73	13.37	10.18	16.04	8.10
FeO (ferrous oxide)	—	—	—	—	—	—
Al_2O_3 (alumina)	26.77	7.56	16.63	14.29	17.05	15.02
MnO (manganese oxide)	—	0.08	0.16	0.24	0.18	0.08
CaO (lime)	—	19.32	4.64	7.54	1.74	2.11
MgO (magnesia)	0.27	3.96	3.28	4.53	1.52	1.63
K_2O (potash)	—	0.67	0.01	0.17	0.76	1.31
Na_2O (soda)	—	0.76	0.80	0.29	0.65	1.29
P_2O_5 (phosphorus pentoxide)	—	tr.	0.06	0.08	0.25	0.08
SO_3 (sulphur trioxide)	—	0.12	0.07	0.02	0.08	0.02
N (nitrogen)	—	0.05	tr.	0.07	0.27	0.07
Ignition loss	—	21.22	10.82	10.98	17.08	6.87
Moisture	—	5.30	2.75	5.82	8.35	7.20
CO_2 (carbon dioxide) from carbonates	—	16.73	none	4.82	none	none
"Humus"	9.19	—	—	—	—	—

I. Sample from Cape Town collected by Pechuel-Loesche and published by Sachsse in "Lehrbuch der Agrikulturchemie," republished by Wohltmann in "Die natürlichen Faktoren der tropischen Agrikultur und die Merkmale ihrer Beurteilung," Leipzig, 1892, p. 147.

II. Sample from Low Veld 20 miles northwest of Pretoria collected by Shantz at depth of 3 feet. Analysis by G. J. Hough in laboratory of U. S. Bureau of Soils.

III. Sample collected by Shantz from excavation in street of Bulawayo at depth of 3 feet, from immediately above the zone of carbonate accumulation. Analysis by W. O. Robinson and G. J. Hough in laboratory of U. S. Bureau of Soils. (See Figs. 41 and 43.)

IV. Same locality as III, taken at depth of 4 to 5 feet.

V. Sample collected by Shantz between Nairobi and Fort Hall, Kenya Colony. Surface soil to depth of about 1 foot. Analysis by Hough in laboratory of U. S. Bureau of Soils.

VI. Sample collected by Shantz at Shikaba on the White Nile, Anglo-Egyptian Sudan, at depth of 2 feet. Probably alluvium. Analysis by Hough in laboratory of U. S. Bureau of Soils.

CHEMICAL ANALYSES OF AFRICAN SOILS

(*Continued*)

	VII	VIII	IX	X	XI	XII
SiO_2	34.16	64.36	66.32	62.24	63.47	60.91
TiO_2	3.12	1.49	1.32	1.20	1.17	1.67
Fe_2O_3	14.15	7.49	7.05	7.53	7.52	8.32
FeO	—	0.90	—	—	—	—
Al_2O_3	25.55	17.16	16.10	20.06	19.11	19.62
MnO	0.38	0.05	0.06	tr.	0.03	0.03
CaO	1.09	0.32	0.07	0.08	0.27	0.10
MgO	0.37	0.65	0.85	0.25	0.23	0.23
K_2O	0.34	1.01	1.01	1.37	0.93	1.32
Na_2O	0.09	0.09	0.01	0.32	0.20	0.12
P_2O_5	—	0.07	0.06	0.07	0.12	0.03
SO_3	—	0.02	0.07	0.05	0.02	0.02
N	—	0.02	0.08	0.07	0.05	0.05
Ignition loss	9.24	7.18	7.66	7.73	6.68	8.08
Moisture	11.10	1.41	1.27	1.34	2.07	1.22
CO_2	—	none	—	none	none	none

VII. Sample collected by H. B. Maufe on Uganda Railway not far from Makindu. Red clay at depth of 4 feet. Published in "Report Relating to the Geology of the East Africa Protectorate," *Misc. Colonial Repts. No. 45*, London, 1908.

VIII. Sample collected by Shantz from middle of ant hill at Elizabethville, Belgian Congo. Analysis by W. O. Robinson and R. S. Holmes in laboratory of U. S. Bureau of Soils.

IX. Sample collected by Shantz at depth of 6 inches beneath rich growth of bracken at Elizabethville, Belgian Congo. Analysis by Robinson and Holmes in laboratory of U. S. Bureau of Soils.

X. Same as IX, at depth of 1 foot. Same analysts.

XI. Same as IX, taken at depth of 24 inches. Analysis by Holmes in laboratory of U. S. Bureau of Soils.

XII. Same as IX, taken at depth of 42 inches. Same analyst.

CHEMICAL ANALYSES OF AFRICAN SOILS

(*Continued*)

	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII
SiO_2	80.95	66.56	79.73	75.91	67.06	80.50	59.82	73.41	44.73	45.46
TiO_2	0.74	0.98	0.80	0.80	0.88	—	1.43	0.89	1.43	1.57
Fe_2O_3	3.29	10.21	3.85	4.68	6.36	—	12.32	5.03	13.66	12.60
FeO	—	—	—	—	—	4.00	—	—	—	—
Al_2O_3	9.35	14.89	9.94	12.46	12.94	11.10	18.14	12.70	26.89	25.35
MnO	0.08	0.04	0.07	0.08	7.09	—	0.30	0.02	0.21	0.44
CaO	0.26	0.09	0.28	0.92	0.09	0.20	0.16	0.57	0.05	0.39
MgO	0.08	0.24	0.05	0.04	0.13	0.10	0.19	0.32	0.28	0.46
K_2O	0.86	1.06	1.00	0.84	1.09	0.20	0.32	0.83	0.51	0.47
Na_2O	0.46	0.28	0.14	0.16	0.01	0.20	tr.	0.59	tr.	tr.
P_2O_5	0.08	0.10	0.11	0.09	0.05	—	0.26	0.11	0.21	0.33
SO_3	0.03	0.01	0.04	0.03	0.02	—	0.25	0.02	0.03	0.05
N	0.05	0.03	0.03	0.07	0.03	—	0.06	0.05	0.08	0.14
Ignition loss	4.45	6.31	4.56	5.18	5.32	4.00	6.92	5.27	12.15	13.21
Moisture	1.06	1.61	1.24	1.20	1.44	—	1.99	1.65	2.89	3.18
CO_2	none	none	none	none	none	—	none	none	none	none

XIII. Sample collected by Shantz on Lualaba between Luenga and Kongolo, Belgian Congo. Surface soil. Analysis by Holmes in laboratory of U. S. Bureau of Soils. (See Fig. 47.)

XIV. Same as XIII, taken at depth of 15 inches. Same analyst.

XV. Same as XIII, taken at depth of 36 inches. Same analyst.

XVI. Same as XIII, taken at depth of 54 inches. Same analyst.

XVII. Same as XIII, taken at depth of 72 inches. Analysis by Robinson in laboratory of U. S. Bureau of Soils.

XVIII. Sample from Malanye, Portuguese West Africa, collected by Buchner. Analysis by Schwager, published in Eduard Pechuel-Loesche: Westafrikanische Laterite, *Ausland*, 1884, pp. 401–407 and 422–428; reference on p. 426, Stuttgart.

XIX. Sample collected by Shantz from sloping field at Nyanza, Lake Tanganyika. Taken at depth between 3 and 4 feet. Analysis by F. A. Barker in laboratory of U. S. Bureau of Soils.

XX. Sample collected by Shantz at Ankoro, Belgian Congo, from depth of 1 foot. Analysis by Hough in laboratory of U. S. Bureau of Soils.

XXI. Sample collected by Shantz to depth of 1 foot near Rusoka in highlands of Urundi, Belgian Congo. Analysis by Barker in laboratory of U. S. Bureau of Soils.

XXII. Same as XXI, collected at depth of 1½ feet. Same analyst.

CHEMICAL ANALYSES OF AFRICAN SOILS

(*Continued*)

U. S.

	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX	XXXI
SiO_2	61.86	65.38	39.90	37.90	38.20	38.94	10.62	70.66	51.58
TiO_2	2.89	0.56	1.40	3.98	4.04	3.61	—	1.12	0.78
Fe_2O_3	5.76	4.38	4.84	14.82	14.60	14.98	4.26	5.03	7.02
FeO	—	—	—	—	—	—	—	—	—
Al_2O_3	19.90	20.38	12.44	28.03	28.74	28.63	54.24	13.18	27.98
MnO	0.27	0.04	0.16	0.32	0.29	0.30	—	0.32	0.09
CaO	0.09	0.40	4.64	0.78	0.59	0.50	tr.	0.26	0.36
MgO	0.40	0.16	0.93	0.33	0.11	0.37	tr.	0.30	0.31
K_2O	0.12	0.22	1.29	1.00	0.82	0.81	0.78	1.38	1.02
Na_2O	tr.	0.59	0.61	0.47	0.44	0.36	1.36	0.20	0.16
P_2O_5	0.38	tr.	0.43	0.70	0.84	0.72	0.04	0.10	0.17
SO_3	0.09	0.02	0.31	0.08	0.08	0.07	—	0.12	0.13
N	0.16	0.06	1.19	0.07	0.05	0.04	—	0.09	0.04
Ignition loss	9.58	8.17	32.81	12.16	11.73	11.36	H_2O	7.80	11.15
Moisture	1.56	1.50	7.03	3.43	3.06	3.36	27.94	1.40	1.75
CO_2	none	—	—	—	—	—	—	—	—

XXIII. Sample collected by Shantz at Soga, Tanganyika Territory. Surface soil. Analysis by Barker in laboratory of U. S. Bureau of Soils.

XXIV. Same as XXIII, taken at depth of 2½ feet. Analysis by Hough in laboratory of U. S. Bureau of Soils.

XXV. Sample collected by Shantz at Moshi, Tanganyika Territory. Surface sample. Analysis by Robinson in laboratory of U. S. Bureau of Soils.

XXVI. Same as XXV, from depth of 1 foot. Analysis by Holmes.

XXVII. Same as XXV, from depth of 3 feet. Analysis by Holmes.

XXVIII. Same as XXV, from depth of 6 feet. Analysis by Holmes.

XXIX. Sample of laterite concretions from Amani Experiment Station tract, Tanganyika Territory, analyzed by H. Süssenguth and published in W. Koert: Geologisch-agronomische Untersuchung der Umgegend von Amani in Ostusambara, *Berichte über Land- und Forstwirtschaft in Deutsch-Ostafrika*, Vol. 2, 1904, pp. 143–164, Heidelberg.

XXX. Sample of red loam from Troup County, Georgia, U. S. A. Surface soil to depth of 11 inches. Analysis by Hough in laboratory of U. S. Bureau of Soils.

XXXI. Same as XXX, collected at depth from 11 to 36 inches. Same analyst.

PART III
LAND CLASSIFICATION OF AFRICA

CHAPTER X

THE LANDS OF AFRICA ACCORDING TO THEIR POTENTIAL PRODUCTIVITY

In the development of an area newly opened up to European civilization, like Africa, it is essential for a rational utilization of its resources to know for what form of economy its various parts are best suited. Although the mineral resources of Africa include coal and various metals, especially gold, the predominant value of the continent lies in its agricultural possibilities (using the term agriculture in its widest sense to include animal husbandry and forestry). A knowledge of these possibilities, therefore, encompasses a large share of the information necessary for a proper evaluation of the resources of the continent.

The Land Classification Map

It is with this thought in mind that the accompanying land classification map (Pl. II) has been prepared. It divides Africa up into various areas according to their agricultural potentiality and shows for what types of utilization each area is suited and the degrees of potential productivity within each type.

To arrive at a conclusion as to the agricultural possibilities of an area it is necessary to know the character of its climate, its soils, and its natural vegetation. Natural vegetation represents a complete adjustment of plants to their environment, while soils, as has been shown in Part II of this work, closely reflect the climatic conditions under which they were formed. Both thus afford a valuable guide to the range of potential production of a given region. The land classification map is therefore based on the vegetation map and the soil map. The soils are known only in very general terms, and the detailed portions of the land classification map are therefore based almost entirely on the vegetation map. Areas which coincide in outline on the

vegetation map and the soil map were retained as units on the land classification map. Where the same type of vegetation is shown to extend over several types of soil, such, for example, as residual and alluvial lands which differ in suitability for crop production, this difference was shown on the land classification map. Broad soil and plant types were recognized in so far as possible. The land classification map is not merely the result of superimposing the soil and vegetation maps. Many of the areas which would be segregated in this way have been reunited in order to reduce the number of classes and make the distinctions of greater significance.

The areas are graded according to agricultural potentiality, each type of area being distinguished by a letter from A to W, in decreasing order of value, and by a separate color. "A" lands thus include the Nile valley and delta, the most fertile parts of the continent, while, at the other end of the scale, "W" lands include the Sahara. In addition to this estimate of the relative value of the various kinds of land, an estimate has been attempted of their value within each type of utilization for which they are fitted. This estimate is expressed in the legend of the map, five grades of productivity, from very high to very low, being indicated for each of the four types of land utilization here established for which each area is suited, whether as (1) tropical agricultural land, (2) subtropical or temperate agricultural land, (3) grazing land, or (4) forest land. The letters in the legend indicate to which type of utilization and to what degree of potential productivity each area has been assigned.

Symbols Designating Each Type of Land

As this form of explanation shows mainly what areas are classed under a certain type of utilization but does not show at a glance for what types of utilization each individual area is suited, it has been thought well to devise a designation which would concisely characterize each area. This has been done in the form of algebraic expressions in which the symbols have the following significance:

Letters Expressing Type of Land		*Powers Expressing Degree of Productivity*	
A	Tropical agricultural land	^{1}	Very low productivity
a	Subtropical and temperate agricultural land	^{2}	Low productivity
		^{3}	Medium productivity
G	Grazing land	^{4}	High productivity
F	Forest land	^{5}	Very high productivity

The types of land utilization for which certain areas are suited and the degree of productivity of each type would, for example, be expressed as follows:

$$\mathrm{A} = A^5G^1F^5$$
$$\mathrm{B} = a^5G^1F^5$$
$$\mathrm{S} = A^1a^1G^3F^1$$

These expressions have been placed directly under the letter designating each type of land in the synopsis that follows.

Synopsis of Characteristics of Each Type of Land

This synopsis constitutes a characterization of each type of land. Under each type are taken up in order and briefly discussed the following topics: relative productivity (rank of productivity within the whole group of 23 types), soil type, topography and climate, vegetation type, natural products, and agricultural potentialities.

A

$A^5G^1F^5$

RELATIVE PRODUCTIVITY

Very high.

SOIL TYPE

Light-colored alluvium, usually loamy or heavier.

TOPOGRAPHY AND CLIMATE

Level. Warm and humid. Rainfall 30–120 inches. Usually no drought period.

VEGETATION TYPES

Mainly tropical rain forest or marsh grass.

NATURAL PRODUCTS

Palm oil and nuts, rubber and timber.

AGRICULTURAL POTENTIALITIES

Cacao, bananas, rice, sugar cane, vanilla, manioc, yams, ginger, rubber, coffee, arrowroot, coconuts, maize, sorghum, eleusine, sweet potatoes, cotton, tobacco, beans, indigo, groundnuts, pennisetum, sesame, and tropical fruits and vegetables.

B

$a^5G^1F^5$

RELATIVE PRODUCTIVITY

Very high.

SOIL TYPE

Red loam moderately deep, no hardpan, moderate leaching. Generally complex mineral composition. Fresh soil, low in organic matter, free from laterites.

TOPOGRAPHY AND CLIMATE

Mountainous. Humid, warm to temperate. Rainfall 40–80 inches. No drought period.

VEGETATION TYPE

Mostly temperate rain forest.

NATURAL PRODUCT

Timber.

AGRICULTURAL POTENTIALITIES

Temperate crops such as wheat, oats, barley, rye, potatoes, maize, sorghum, eleusine, pennisetum, flax, groundnuts, cotton, beans, peas, sweet potatoes, yams, coffee, bananas, subtropical fruits, temperate fruits and vegetables.

C

a^5G^5

RELATIVE PRODUCTIVITY

Very high.

SOIL TYPE

Dark reddish loams, free from hardpan, moderately leached and moderately complex mineral composition.

TOPOGRAPHY AND CLIMATE

High rolling to mountainous. Moderate humidity. Warm, temperate. Rainfall 40–60 inches. No prolonged drought period.

VEGETATION TYPE

Mountain grassland.

NATURAL PRODUCTS

Most valuable grazing land.

AGRICULTURAL POTENTIALITIES

Wheat, barley, oats, rye, maize, sorghum, millet, flax, manioc, groundnuts, cotton, beans, peas, sweet potatoes, bananas, coffee, subtropical fruits, temperate fruits and vegetables.

D

$A^5G^2F^3$

RELATIVE PRODUCTIVITY

Very high.

SOIL TYPE

Red loams moderately leached.

TOPOGRAPHY AND CLIMATE

Smooth rolling land. Rainfall moderate to high, 30–80 inches. Tropical. Drought period three to five months.

VEGETATION TYPE

Mostly high grass-low tree savana.

NATURAL PRODUCTS

Grazing, rubber, and oil.

AGRICULTURAL POTENTIALITIES

Groundnuts, sorghum, eleusine, pennisetum, maize, cotton, sweet potatoes, yams, tropical fruits and vegetables, sesame, manioc, tobacco, beans, indigo, and rubber.

E

a^4G^4

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Dark brown to red-brown. Sandy loams to loams.

TOPOGRAPHY AND CLIMATE

A high plateau. Summer rains, 30–40 inches. Drought period four to six months.

VEGETATION TYPE

Tall grass.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Temperate dry-land crops: wheat, oats, barley, rye, sorghum, maize, and millet; temperate fruits: pears, plums, apricots, peaches, and figs; and temperate vegetables.

F

$A^4G^3F^3$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Dark-colored humid soils.

TOPOGRAPHY AND CLIMATE

Smooth topography. Rainfall 35–45 inches. Drought period two to five months.

VEGETATION TYPES

Acacia-tall grass savana, high grass-low tree savana.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Maize, sorghum, pennisetum, eleusine, cotton, sweet potatoes, yams, and tropical fruits and vegetables.

G

$a^4G^6F^3$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Heavy black soil.

TOPOGRAPHY AND CLIMATE

Smooth topography. Rainfall 20–30 inches. Drought period three to five months.

VEGETATION TYPE

Acacia-tall grass savana.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Maize, sorghum, pennisetum, sweet potatoes, tobacco, beans, groundnuts, wattle, cotton, and subtropical fruits and vegetables.

H

$a^4G^2F^2$

RELATIVE PRODUCTIVITY

High.

SOIL TYPES

Brown soils with reddish subsoils.

TOPOGRAPHY AND CLIMATE

Varied; mountain ranges with intervening longitudinal valleys. Rainfall 20–30 inches, rather equally distributed.

VEGETATION TYPES

Temperate brush, oak-conifer forest, temperate forest of Cape.

NATURAL PRODUCTS

Firewood and browse.

AGRICULTURAL POTENTIALITIES

Temperate cereals: wheat, barley, oats, rye, maize, and sorghum; tobacco, alfalfa, and semitropical and temperate fruits, especially grapes.

I

$A^4G^1F^5$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Red loams. Probably lateritic.

TOPOGRAPHY AND CLIMATE

Rolling to hilly lands. Warm and humid. Rainfall 60–80 inches. Drought period short or lacking—not sufficient to cause leaf fall.

VEGETATION TYPE

Tropical rain forest.

NATURAL PRODUCTS

Palm oil and nuts, rubber, timber, kola, and copal.

AGRICULTURAL POTENTIALITIES

Cacao, bananas, rice, sugar cane, vanilla, manioc, yams, ginger, rubber, coffee, arrowroot, coconuts, maize, sorghum, pennisetum, eleusine, sweet potatoes, yams, cotton, tobacco, beans, indigo, groundnuts, sesame, and tropical fruits and vegetables.

J

$A^4G^3F^3$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Dark-colored soils, often calcareous subsoils.

TOPOGRAPHY AND CLIMATE

Smooth lowlands and plateaus. Rainfall 20–35 inches. Drought period three to six months in midwinter.

VEGETATION TYPES

Acacia-tall grass savana, high grass-low tree savana.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Sorghum, peanuts, cotton, pennisetum, beans, manioc, yams, sweet potatoes, indigo, tobacco, sesame, and cucurbits and other vegetables.

K

$A^4G^2F^4$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Red loams and sandy loams.

TOPOGRAPHY AND CLIMATE

Undulating, gently rolling. Fair rainfall, 30–40 inches. Long drought period, four to six months in midwinter.

VEGETATION TYPE

Dry forest.

NATURAL PRODUCTS

Grazing; gums, timber, and rubber.

AGRICULTURAL POTENTIALITIES

Maize, sorghum, pennisetum, cotton, sweet potatoes, sesame, tobacco, beans, indigo, groundnuts, eleusine, and rubber.

L

$A^4G^2F^3$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Red loams occasionally dark in color.

TOPOGRAPHY AND CLIMATE

Rolling plains to hilly lands. Rainfall 35–45 inches. Drought period three to five months.

VEGETATION TYPE

Acacia-tall grass savana.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Maize, sorghum, pennisetum, manioc, yams, sweet potatoes, sesame, tobacco, beans, indigo, groundnuts, sisal, rubber, bananas, pineapple, and other tropical fruits and vegetables.

M

$A^4G^2F^4$

RELATIVE PRODUCTIVITY

High.

SOIL TYPE

Gray to red soils, often heavy subsoils. Frequent lime accumulations.

TOPOGRAPHY AND CLIMATE

Rolling to undulating. Rainfall 25–35 inches. Drought period three to six months.

VEGETATION TYPES

Acacia-tall grass savana and dry forest.

NATURAL PRODUCTS

Grazing; timber.

AGRICULTURAL POTENTIALITIES

Sorghum, peanuts, cotton, pennisetum, beans, manioc, yams, sweet potatoes, indigo, tobacco, sesame, and cucurbits and other vegetables.

N

$A^3G^1F^5$

RELATIVE PRODUCTIVITY

Medium.

SOIL TYPE

Laterites.

TOPOGRAPHY AND CLIMATE

Rolling to mountainous. Rainfall 70–160 inches. Drought period short or lacking, not sufficient to cause leaf fall.

VEGETATION TYPES

Tropical rain forest and high grass-low tree savana.

NATURAL PRODUCTS

Timber and rubber.

AGRICULTURAL POTENTIALITIES

Cacao, banana, rice, sugar cane, vanilla, manioc, yams, ginger, rubber, coffee, arrowroot, coconuts, maize, sorghum, eleusine, sweet potatoes, cotton, tobacco, beans, indigo, groundnuts, pennisetum, sesame, and tropical fruits and vegetables.

O

$A^3G^2F^3$

RELATIVE PRODUCTIVITY

Medium.

SOIL TYPE

Red loams, with iron oxide accumulation in the subsoils, Kasai basin.

TOPOGRAPHY AND CLIMATE

Smooth interstream plains and plateau remnants. Rainfall 50–65 inches. Drought period three to five months.

VEGETATION TYPE

High grass-low tree savana.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Groundnuts, sorghum, eleusine, pennisetum, maize, cotton, sweet potatoes, yams, tropical fruits and vegetables, sesame, manioc, tobacco, beans, indigo, and rubber.

P

$a^3G^3F^2$

RELATIVE PRODUCTIVITY

Medium.

SOIL TYPE

Brown to dark-brown soils with calcareous subsoils.

TOPOGRAPHY AND CLIMATE

Smooth intermountain valleys and plains. Temperate rainfall 15–30 inches. Drought period two to three months in north and three to six months in south.

VEGETATION TYPES

Dwarf palm-temperate grass, acacia-tall grass savana, desert grass-desert shrub.

NATURAL PRODUCTS

Grazing and palm fiber.

AGRICULTURAL POTENTIALITIES

Temperate cereals: wheat, barley, oats, rye, maize, and sorghum; tobacco, alfalfa, and temperate and subtemperate fruits.

Q

$A^3G^3F^2$

RELATIVE PRODUCTIVITY

Medium.

SOIL TYPE

Sands and dark-colored sandy alluvial and lowland soils of the Lake Chad basin and bend of the Niger. Free from hardpan.

TOPOGRAPHY AND CLIMATE

Level. Rainfall low, 15–30 inches. Drought period five to seven months in midwinter.

VEGETATION TYPE

The drier portion of acacia-tall grass savana.

NATURAL PRODUCTS

Grazing; gums.

AGRICULTURAL POTENTIALITIES

Maize, sorghum, sweet potatoes, cotton, tobacco, beans, indigo, groundnuts, and pennisetum.

R

$A^2a^2G^3F^2$

RELATIVE PRODUCTIVITY

Low.

SOIL TYPE

Grayish sands with considerable organic matter. Moderately leached.

TOPOGRAPHY AND CLIMATE

Sandy plain with summer rainfall and high temperature. Rainfall 20–30 inches. Drought period about six months in midwinter.

VEGETATION TYPE

Acacia-tall grass savana.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Sorghum and pennisetum, maize and similar dry-land crops and vegetables.

S

$A^1a^1G^3F^1$

RELATIVE PRODUCTIVITY

Very low.

SOIL TYPE

Gray to red sands not extensively leached.

TOPOGRAPHY AND CLIMATE

Sandy plain with low summer rainfall, 10–20 inches, and high temperature.

VEGETATION TYPE

Acacia-desert grass savana.

NATURAL PRODUCT

Good grazing land of low carrying capacity where drinking water can be secured.

AGRICULTURAL POTENTIALITIES

Dry-farm crops (cereals) only during favorable years and on the better soils.

T

G^3F^1

RELATIVE PRODUCTIVITY

Very low.

SOIL TYPE

Gray, wet, sandy alluvium, often charged with salts.

TOPOGRAPHY AND CLIMATE

Flat and hot. Rainfall 20–30 inches. Much of area flooded in rainy season.

VEGETATION TYPES

Dry forest. Sub-irrigated grasslands and marsh grass.

NATURAL PRODUCT

Grazing.

AGRICULTURAL POTENTIALITIES

Hay or forage crops where not too salty.

U

G^2

RELATIVE PRODUCTIVITY

Very low.

SOIL TYPE

Brown sandy loams, or heavier, unleached, high in soluble constituents. Probably a chemical hardpan.

TOPOGRAPHY AND CLIMATE

Desert types: varied topography. Very low rainfall, 5–10 inches. Long hot, dry season. Alpine meadow: high-peak topography. Cold climate.

VEGETATION TYPES

Desert shrub, desert shrub-desert grass, and alpine meadow.

NATURAL PRODUCT

Grazing land of low carrying capacity.

AGRICULTURAL POTENTIALITIES

Dry farm crops: barley, sorghum, millet, etc., during favorable years only. Alpine meadow (no potentialities).

V

F[4]

RELATIVE PRODUCTIVITY

None.

SOIL TYPE

Brackish, swamp soil.

TOPOGRAPHY AND CLIMATE

Submerged, hot.

VEGETATION TYPE

Mangrove.

NATURAL PRODUCTS

Tannin and timber.

AGRICULTURAL POTENTIALITIES

None.

W

None.

RELATIVE PRODUCTIVITY

None.

SOIL TYPE

Gray, sandy desert. Calcareous, unleached.

TOPOGRAPHY AND CLIMATE

Smooth to rough. Dry and hot. Rainfall 2–5 inches.

VEGETATION TYPES

Desert shrub, desert.

NATURAL PRODUCTS

None.

AGRICULTURAL POTENTIALITIES

None.

NOTE ON
THE RAINFALL MAP OF AFRICA

NOTE ON THE RAINFALL MAP OF AFRICA

By J. B. Kincer

The importance of rainfall in the growth of plants needs no elaboration. In the case of Africa, a continent which lies on both sides of the equator and extends to both temperate zones and which has no excessive differences of elevation over broad areas, the distribution of temperature is fairly schematic. Of the two climatic elements having the most important bearing on the distribution of vegetation and on agricultural possibilities, rainfall is therefore the one which is in greater need of representation. This need it has been attempted to supply in the accompanying map of Africa showing the mean annual amount of rainfall (inset, Pl. II).

The map is based on the records of 757 stations. The mean annual amount of rainfall in inches (transformed from metric equivalents where necessary) and the length of record were plotted for each of these stations on a map of Africa on the scale of 1:5,000,000. The isohyetals for, as a rule, every 10 inches of rainfall were then drawn, consideration being taken of elevation, winds, and other factors where the station net is not sufficiently close to control the position of the isohyetals. This map was reduced by photo-engraving to the 1:25,000,000 scale of the accompanying map.

While the map is an original compilation its main purpose is to serve as a means of correlating rainfall with soils and vegetation in this book. As the records available, because of the time elapsed, necessarily cover longer periods for most stations than the records available to the previous investigators of this subject and as, also, new stations have since been established, the present map may furnish a somewhat more advanced picture than its predecessors. In its broad features it resembles

them closely, of course, and to the publications[1] which they accompany the reader is therefore referred, especially to those of Hann, Fraunberger, and Knox, for a discussion of the distribution of rainfall in Africa and its causes.

The records of the stations used in preparing the map are too voluminous for publication here. Copies of these records, with a list of the sources from which they were taken, may, however, be secured from the American Geographical Society by any interested reader of this book. Of most of the 757 stations in the list are given (1) the latitude and longitude, (2) the elevation in feet, (3) the length of the record, (4) the mean amount of rainfall for each of the twelve months, and (5) the mean annual rainfall.

[1] Alexander Supan: Die Verteilung des Niederschlags auf der festen Erdoberfläche. 103 pp. *Petermanns Mitt. Ergänzungsheft No. 124.* Gotha, 1898. With mean annual rainfall map of the world on Mercator's projection, equatorial scale 1: 100,000,000, and records of 204 African stations.

A. J. Herbertson: The Distribution of Rainfall Over the Land. 70 pp. Royal Geographical Society, London, 1901. With rainfall map of the two hemispheres on Lambert's equal-area azimuthal projection, 1: 92,000,000, for each month and for the year, and records of 8 African stations supplemental to those published by Supan. The rainfall map for the year is reproduced on a continuous surface in Mollweide's projection, 1: 85,000,000, in J. G. Bartholomew and A. J. Herbertson: Atlas of Meteorology, Edinburgh, 1899, Pl. 18.

Georg Fraunberger: Studien über die jährlichen Niederschlagsmengen des afrikanischen Kontinents, *Petermanns Mitt.*, Vol. 52, 1906, pp. 73–82. With mean annual rainfall map of Africa, 1: 25,000,000 (Pl. 7), and records of 368 African stations exclusive of the Atlas Region and South Africa.

Julius Hann: Handbuch der Klimatologie, 3rd edit., Vol. 2, pp. 32–194, Vol. 3, pp. 36–90, Stuttgart, 1910 and 1911. With rainfall map of Africa south of the Sahara, 1: 100,000,000, in Vol. 2, p. 35.

Alexander Knox: The Climate of the Continent of Africa. 552 pp. Cambridge, England, 1911. With rainfall maps of Africa, 1: 40,000,000, for each month and for the year.

INDEX

INDEX

Names of authors contained in the List of References are not indexed. For these names see that list, pp. 85–112.

Abyssinia, soils, 151
Acacia albida Delile, 48, 55
Acacia arabica Willd., 43, 48, 56
Acacia arabica kraussiana Benth., 56
Acacia dentinens Burch., 43, 64
Acacia giraffae Willd., 55, 64
Acacia hebeclada DC., 43, 64
Acacia heteracantha Burch., 43, 64
Acacia horrida Willd., 43, 57, 63
Acacia kirkii Oliver, 38
Acacia nigrescens Oliver, 39
Acacia Senegal Willd., 43
Acacia seyal Delile, 56
Acacia spirocarpoides Engl., 43, 56
Acacia suma Kurz, 51
Acacia tortilis Hayne, 43
Acacia verek Guill. & Perr., 43
Acacia-desert grass savana, 10; agriculture, 66; area, 19; botanical description, 63; climatic conditions, 65; detailed description, 63; distribution, 64; general view (ill.), opp. 64; natural production, 65; productivity, relative and potential, 239; soil conditions, 65; thorn forest and, 44; typical view (ill.), opp. 65
Acacia-tall grass savana, 10; agriculture, 58; area, 19; botanical description, 55; comparison with adjacent communities, 57; crop potentialities, 59; detailed description, 55; distribution, 56; general view (ill.), opp. 56; grassland with flat-topped acacias (ill.), opp. 57; native planting of sweet potato (ill.), opp. 58; natural production, 57; orange orchard (ill.), opp. 59; productivity, relative and potential, 231, 233, 235, 237, 238, 239; section of chernozem soil at Bulawayo (ills.), opp. 158, opp. 159; section of chestnut-brown soil (ill.), opp. 158; sorghum field (ill.), opp. 57; thorn forest and, 44
Acacias, 42, 55; opp. 64 (ill.), opp. 65 (ill.); thicket in drought (ill.), opp. 44
Acanthosicyos horrida Welw., 83
Acknowledgments, vii
Adansonia digitata L., 56
Addo bush, 43, 44
Adenocarpus sp., 72
Aeschynomene elaphroxylon (Guill. & Perr.) Taub., 74
Africa, territorial divisions, route of H. L. Shantz, location of soil samples (map), viii–ix
African nutmeg, 29
African soils, history of the study of, 131. *See also* Soils
African vegetation, 3. *See also* Vegetation
Afrimomum, 32
Agauria salicifolia Hook., 33
Agricultural experiment stations, 132, 136; Amani, 133, 198, 215, 221; Bonn-Poppelsdorf, 210, 216
Agricultural land, area occupied by each type, 22; productive, 18
Agriculture, possibilities, 225; potentialities, brief general survey, 14. *See also* Crop potentialities
Agriculture of the vegetation types, 14; acacia-desert grass savana, 66; acacia-tall grass savana, 58; desert shrub, 81; desert shrub-desert grass, 78; dry forest, 41; dwarf palm-temperate grass, 73; high grass-low tree savana, 53; mangrove forest, 25; marsh grass, 75; mountain grassland, 69; oases, 49; salt desert shrub, 82; tall grass, 62; temperate brush, 47; temperate rain forest, 35; tropical rain forest, 30. *See also* Crop potentialities; Productivity
Agriculture, Department of, vii
Agriculture, Secretary of, x
Agronomists, soil study by, 116
Albert, Lake, region, 155
Alexandersfontein, opp. 81
Algeria, cedar forest (ill.), opp. 36

Alkali, black and white, 81; deserts and, 179, 180; prairie soils and, 153
Alloteropsis semialata (R. Br.) Hitchc., 39
Alluvial land, 28; high grass-low tree savana, 52; oases, 49; productivity, relative and potential, 227, 238, 240
Aloe dichotoma L., 79
Alpine meadow, 13; area, 19; botanical description, 71; detailed description, 71; distribution, 71; productivity of land, relative and potential, 241
Alteration of rocks in the tropics, 187
Alumina, 184, 187; laterites and, 126
Aluminum hydroxide, 126, 127, 184, 186, 188, 189, 208
Aluminum silicate, 126, 127, 187
Amani, 133, 198, 215, 221
Ambash, 73, 75
American Commission to Negotiate Peace, vii
American Geographical Society, x, 246
Ampelodesma tenax Link, 72
Amphiloma elegans, 71
Anabasis aretioides Moq. & Coss, 80, 83
Anabasis articulata Moq., 80
Analysis of soils, 133, 135; acid-soluble method, 136, 153; important elements, 135; red loams, 194, 219, 220; table of chemical analyses of African soils, 218–221
Andropogon, 51
Andropogon amplectens Nees, 61
Andropogon exothecus, 71
Andropogon hirtiflorus Kunth, 56, 61
Andropogon lepidus Nees, 51
Andropogon rufus Kunth, 51
Andropogon ruprechtii Hack., 56
Andropogon schimperi Hochst., 51
Andropogon schirensis Hochst., 61
Andropogon scoparius, 60
Andropogon tenuiberbis Hack., 51
Angoulvant, G., 164
Animals, domestic, 16; game centers, 14
Annona, 51
Appalachian Piedmont region, southern, 168
Archer's Post, opp. 57, opp. 66
Argentina, 191, 192
Arid soils, 179
Aristida (ill.), opp. 76
Aristida adscensionis L., 76
Aristida brevifolia Steud., 76
Aristida burkei Stapf, 64
Aristida capensis Thunb., 76
Aristida ciliate Desf., 77
Aristida congesta Roem. & Schult., 64
Aristida dregeana Trin. & Rupr., 76
Aristida hordeacea Kunth, 64
Aristida namaquensis Trin. & Rupr., 77
Aristida obtusa Delile, 76
Aristida plumosa, L., 76
Aristida pungens Desf., 76, 83
Aristida rangei Pilg., 64, 76
Aristida sp., 68
Aristida stipiformis Lam., 64
Aristida subacaulis Steud., 76
Aristida uniplumis Lichtst., 64
Aristida vestita Thunb., 76
Arsandaux, H., 201, 202, 206, 208, 210, 211, 216
Artemisia campestris L., 80
Artemisia herba-alba Asso, 80
Arundinaria alpina Schum., 33, 72
Aruwimi-Rubi region, 203
Asparagus sp., 43
Aster serrulatus Harv., 61
Athi Plains, 149, 162, 165, 169, 177
Atlas region, soils, 47, 142, 146; vegetation, 13, 36, 45, 72
Atwood, A. C., viii
Aucoumea klaineana, 26
Augea capensis Thunb., 79
Authorities, 23; list of, 85
Avicennia nitida Jacq., 24
Avicennia officinalis L., 24, opp. 24 (ill.)

Baboons, 42, 58
Baikiaea plurijuga Harms., 38
Balanites aegyptiaca Delile, 80
Balanites aegyptiaca (L.) Delile, 43
Ball, S. H., 182, 200, 201, 203
Bamboo, 72
Bambuk region, 211
Bananas, 30, 31, 35, 36
Baobab, 56
Barker, F. A., x, 194, 220, 221
Bartholomew, J. G., 246
Bauer, Max, laterite studies, 183, 214
Bauhinia reticulata DC., 39, 51
Bauxite, 184, 189
Belfast, Transvaal, 202
Belgian Congo, 203
Benue River, 204
Bequaert, J., viii, 155, 203
Berlinia baumii Harms, 38
Berlinia ledermannii Harms, 26
Berthier, M. P., 183
Bertin, André, 26, 86

Bibliography, 85
Bindloss, Harold, 24, 86
Birds, 14; tropical rain forest, 28
Black alkali, 81
Black cotton soil, 164, 169
Black earths. *See* Chernozems
Black soils in Africa, 177, 178; productivity, relative and potential, 231
Black vlei soils, 157, 159
Bombax, 25
Bonn-Poppelsdorf Agricultural Academy, 210, 216
Borassus, 51
Boscia pechuelii Kuntze, 43
Boscia senegalensis Lam., 80
Botanical description of the vegetation types, acacia-desert grass savana, 63; acacia-tall grass savana, 55; alpine meadow, 71; desert, 83; desert shrub, 79; desert shrub-desert grass, 76; dry forest, 38; dwarf palm-temperate grass, 72; high grass-low tree savana, 51; mangrove forest, 23; marsh grass, 73; mountain grassland, 67; oak-conifer forest, 37; oases, 48; salt desert shrub, 82; temperate brush, 45; temperate rain forest, 32; thorn forest, 42; tropical rain forest, 26
Brachiaria brizantha (Hochst.) Stapf, 39
Brachiaria serrata (Spr.) Stapf, 39
Brachystegia randii Baker, 38
Brachystegia spicaeformis Benth., 38
Bracken, 33
Brackish soil, productivity, relative and potential, 241
Brakbosch, opp. 76
British General Staff, 8
Brown desert soils, 180; productivity, relative and potential, 240
Brown soils, 121, 124; productivity, relative and potential, 230, 237; temperate brush, 47
Brown soils of the Cape Province and Atlas region, 47, 142; productivity, relative and potential, 232
Browse, 20, 45
Bruguiera gymnorrhiza Lam., 24
Brush land, 33
Buchanan, Francis, 118, 181
Buchner, Max, 196, 220
Buellia stellulata, 71
Bulawayo, 149, 159; section of chernozem (ills.), opp. 158, opp. 159; soil sample, 157, 218
Bulbous plants, 45, 46
Bureau of Plant Industry, vii
Bureau of Soils, vii, 137, 162, 194, 218–221
Burkea africana Hook., 38
Burkea africana R. Br., 56, 57
Butter tree, 29
Butyrospermum parkii Kotschy, 51

Calcareous nodules, 168, 169
Calcium, 158, 161
Calicedra, 25
California, chernozem, 161; Coast Range, 143; humid soils, 146, 150
Calotropis procera Dryand., 80
Calpocalyx klainei, 26
Camels, 16, 17, 84
Cameroons, 26, 204, 211, 213
Campbell, J. M., laterite studies, 185, 187, 194, 212
Canary Islands, vegetation, 47
Candelaria vitellina, 71
Cape Province, brown soils, 47, 142, 232; flora, 13; soil study by Juritz, 134; vegetation, 45
Carbonate accumulations, 141, 143; black soils in Africa, 177; light-colored chernozems, 167, 169; Natal loams, 151; section of chernozem showing (ill.), opp. 159; section of chestnut-brown soil showing (ill.), opp. 158
Carissa arduina Lam., 44
Carnivora, 14
Cattle, areas, 16; diseases, 16, 17, 18, 20, 59; grazing land area, 21; Masai (ill.), opp. 66
Cattle, areas, 16; grazing law area, 21; Masai (ill.), opp. 66
Cedars, general view (ill.), opp. 36
Cedrus libani Barrel., 37
Cedrus libani var. atlantica (ill.), opp. 36
Ceiba pentandra (L.) *Gaertn.*, 27
Celtis kraussiana Bernh., 32
Central Africa, soils, 181
Ceriops candolleana Arn., 24
Chad, Lake, region, 204, 238
Chamaerops humilis L., 72, opp. 72 (ill.)
Chaparral, 45
Chapin, J. P., viii, 14, 89
Chase, Agnes, x, 39, 67
Chautard, Jean, 200, 202, 206, 209, 216, 217

Chemical analysis. *See* Analysis of soils
Chernozems, 117, 121, 122; association with chestnut-brown soils, 174; black vlei soils and, 157; 159; Cape soils and, 143, 144; extension of areas on basis of climate-topography relationship, 162; Kenya Colony, 157, 161, 175; light-colored, 166; lime carbonate in, 157, 159; Low Veld soils, 158; rainfall and, 160; richness in lime, nitrogen, and phosphorus, 165; samples, analysis, 157, 218; section at Bulawayo (ills.), opp. 158, opp. 159; section at Njoro (ill.), opp. 158; study of, 118; supposed belt across Africa south of the Sahara, 163, 170–171; Texan and African compared, 160, 176; Transvaal areas, 165; typical, 157; unfavorable physical character for crops, 165, 166; United States belts, 161
Chestnut-brown soils, 121, 123; analysis, 219; areas, 171; association with chernozems, 174; description, 171; Kalahari region, 173; Russia, 173; section of soil at Taungs (ill.), opp. 158; Somaliland, 175, 176; Texas, 176; theoretical placing on Sahara border, 174; United States, western, 173
Chevalier, Auguste, 89, 90, 204
Chlorophora excelsa, 26
Chlorophora excelsa (Welw.) Benth. & Hook., 27
Chuca, opp. 32
Cladonia crispata, 71
Clerodendron triphyllum H. H. W. Pearson, 61
Climatic conditions of the vegetation types, acacia-desert grass savana, 65; acacia-tall grass savana, 57; desert, 84; desert shrub, 81; desert shrub-desert grass, 77; dry forest, 40; dwarf palm-temperate grass, 73; high grass-low tree savana, 52; mangrove forest, 24; marsh grass, 74; mountain grassland, 69; oak-conifer forest, 37; oases, 49; tall grass, 62; temperate brush, 47; temperate rain forest, 34; thorn forest, 44; tropical rain forest, 27
Climatic forces, as agents in the production of soils, 119, 138; constancy of soil relation, 175
Clitandra elastica Cheval., 29
Cloud forest, 32
Coast Range region of California, 143
Coffea laurentii Wildem., 29
Coffea ligustrifolia Stapf, 29
Coffea nudiflora Stapf, 29
Coffee, 36
Cohen, E., 158, 165
Collins, G. N., vii, viii
Color in soil, 121; chernozem, variety, 166; redness, 131, 132, 181
Combretum, 55, 57
Combretum apiculatum Sond., 43, 56
Combretum arbuscula Engl. & Gilg, 38
Combretum zeyheri Sond., 56
Conglomérat ferrugineux, 200, 204
Congo forest soils, 213
Conifers, 83. *See also* Oak-conifer forest
Conocarpus erectus Jacq., 24
Copaifera coleosperma Benth., 38
Copaifera mopane J. Kirk, 38
Cork, 37
Corn belt of the United States, 156
Corstorphine, G. S., 158, 165, 201
Coula edulis, 26
Crassula deltoidea L., 79
Crassula lycopodioides Lam., 79
Crassula perfoliata L., 44
Criteria for soil classification, 139
Crook, T., 185, 214
Crop potentialities of the vegetation types, acacia-desert grass savana, 239; acacia-tall grass savana, 59, 231, 233, 235, 237, 238, 239; alpine meadow, 241; desert shrub, 241, 242; desert shrub-desert grass, 237, 241; dry forest, 42, 234, 235, 240; dwarf palm-temperate grass, 237; high grass-low tree savana, 54, 231, 233, 236, 237; mangrove, 241; marsh grass, 228; mountain grassland, 70, 229; oak-conifer forest, 232; tall grass, 230; temperate brush, 48, 232; temperate forest of the Cape, 232; temperate rain forest, 36, 228; tropical rain forest, 30, 31, 228, 233, 236
Crops. *See* Natural production
Crops, soil as an instrument for producing, 116
Ctenium concinnum Nees, 68
Cuirasse ferrugineuse, 200
Curtisia faginea Ait., 32
Cussonia djalonensis Cheval., 51
Cymbopogon afronardus Stapf, 61

Cynodon incompletus Nees, 61
Cynometra alexandri C. H. Wright, 25, 26
Cyperus kersteinii, 72
Cyperus latifolius Poir., 74
Cyperus papyrus L., 73
Cyrenaica, 72

Dark-colored soils, Cape Province, 143, 144, 145; Juritz, C. F., on, 143, 145, 149; Transvaal, 145. *See also* Chernozems; Chestnut-brown soils
Date palm, 48
De Aar, opp. 80, 174
Deniker, J., 18
Desbordesia spp., 26
Deschampsia caespitosa, 71
Desert, 12, opp. 82 (ill.); area, 19; botanical description, 83; climatic conditions, 84; detailed description, 83; distribution, 84; natural production, 84; productivity of land, relative and potential, 242; soil conditions, 84
Desert grass, 11; area, 19; detailed description, 66; open grass cover (ill.), opp. 66
Desert shrub, 11; agriculture, 81; area, 19; botanical description, 79; climatic conditions, 81; detailed description, 78; distribution, 80; natural production, 81; productivity of land, relative and potential, 241, 242; scattered Karroo bush (ill.), opp. 80; soil conditions, 81
Desert shrub-desert grass, 11, opp. 76 (ill.); agriculture, 78; area, 19; botanical description, 76; climatic conditions, 77; detailed description, 76; distribution, 77; natural production, 77; productivity of land, relative and potential, 237, 241; soil conditions, 77
Desert soils, 179, 180; productivity, relative and potential, 241. *See also* Brown desert soils; Gray desert soils
Deserts, total area, 18, 19, 21; vegetation types, detailed description, 76
Dichrostachys nutans Benth., 43, 56
Digitaria argyrotricha (Anderss.) Chiev., 68
Digitaria uniglumis major Stapf, 39
Dikoa, 204
Diospyros mespiliformis Hochst., 38
Diospyros senegalensis Perr., 38
Diseases, cattle, 16, 17, 18, 20, 59
Distribution of vegetation types, acacia-desert grass savana, 64; acacia-tall grass savana, 56; alpine meadow, 71; desert, 84; desert shrub, 80; desert shrub-desert grass, 77; dry forest, 39; dwarf palm-temperate grass, 72; high grass-low tree savana, 51; mangrove forest, 24; marsh grass, 74; mountain grassland, 68; oak-conifer forest, 37; oases, 49; salt desert shrub, 82; tall grass, 62; temperate brush, 46; temperate rain forest, 33; thorn forest, 44; tropical rain forest, 27
Dixon, R. B., 18
Dogs, 16
Dokuchayev, V. V., 119
Domestic animals, 16
Doum palm, 48
Drakensberg, 151
Dry forest, 10; agriculture, 41; area, 19; botanical description, 38; climatic conditions, 40; crop potentialities, 42; detailed description, 37; distribution, 39; general view (ill.), opp. 37; natural production, 40; productivity of land, relative and potential, 234, 235, 240; red loam soil section (ills.), opp. 194, opp. 195; soil conditions, 40, 198
Dumoria heckeli Cheval., 29
Dwarf palm, 72, opp. 72 (ill.)
Dwarf palm-temperate grass, 13, 72, opp. 72 (ill.); agriculture, 73; area, 19; botanical description, 72; climatic conditions, 73; detailed description, 72; distribution, 72; natural production, 73; productivity of land, relative and potential, 237; soil conditions, 73

Eastern Grass Veld, 150
Echinochloa (ill.), opp. 73
Echinochloa pyramidalis (Lam.) Hitch. & Chase, 74
Ehretia hottentotica Burch., 44
Eichinger, ——, 194, 198
Elaeis guineensis Jacq., 27, 29
Elephant grass, 52
Elephantorrhiza burchellii Benth., 61
Eleusine, 69; native field (ill.), opp. 69
Elgon, Mount, 71
Elizabethville, opp. 37, 39, 41, 194, 195, 196, 219
Eluviation, 125, 127

Elytropappus rhinocerotis (L.) Less., 46
Embu, opp. 33, opp. 34, opp. 194
Engler, Adolf, 9, 92
Enneapogon scaber Lehm., 77
Entada sudanica Schweinf., 51
Ephedra alata DC., 83
Ephedra alata Decne, 80
Equatorial forest, 25
Eragrostis brizoides Nees, 61
Eragrostis chalcantha Trin., 39, 68
Eragrostis cilianensis (All.) Link, 68
Eragrostis collocarpa Schum., 68
Eragrostis curvula Nees, 61
Eragrostis gummiflua Nees, 61
Eragrostis olivacea, 71
Eragrostis sp., 68
Eragrostis spinosa Trin., 77
Erica arborea L., 46
Erica corsica DC., 46
Ericas, 33, 45, opp. 45 (ill.), 72
Ericinella mannii, 72
Erigeron canadensis L., 61
Eriocephalus umbellulatus Cass., 46
Eriodendron guineense, 26
Erosion in soil development, 128, 151
Erythrina, 51
Erythrophloeum guineense, 26
Euphorbia, 43
Euphorbia brachiata E. Meyer, 79
Euphorbia cervicornis Boiss., 79
Euphorbia gummifera Boiss., 79
Euphorbia namibensis Marloth, 79
Euryops dacrydioides, 72
Euryops tenuissimus Less., 46
Evans, I. B. P., 93, 150
Evergreens, 45, 46
Expeditions, scientific, 132
Experiment stations, 132, 136; Amani, 133, 198, 215, 221; Bonn-Poppelsdorf, 210, 216
Explorers, early, 131

Fauna, correlation with vegetation areas, 13
Fenneman, N. M., vii
Fermor, L. L., 186, 189, 211
Ferruginous red loams, 190, 199; areas, 203; composition, 200, 201; productivity, 205
Festuca abyssinica, 71
Ficinia gracilis, 72
Ficus, 48
Ficus spp., 48
Fimbristylis atrosanguinea, 72
Fire, 10, 34, 38, 40; as a factor in vegetation, 6
Flahault, Charles, 5, 93
Flat land, 128
Floerkeana sp., 71
Flowering plants, 45, 71, 78
Forests, total area, 18, 19, 21; vegetation types, detailed description, 23
Formations, vegetation, definition, 5, 6; delimitation, 6
Frankenia hirsuta L., 82
Frankenia pulverulenta L., 82
Fraunberger, Georg, 246
French Guinea, 186, 194, 200, 201, 202, 216
French West Africa, 215
Fruit trees, 36
Fruits, 47; oases, 49
Fry, W. H., 194
Funtumia, 28
Funtumia africana (Benth.) Stapf, 29
Funtumia elastica (Preuss.) Stapf, 29
Futa Jallon, 216

Gabon district, 26, 211, 213
Game, 14, 58, 62; dry forest, 40–41
Gardenia, 51
Genista raetam Forsk., 80, 83
Geological Magazine, on laterite, 185
Geological surveys, 133
Geologists, soil study by, 115
Geology, Africa, 137; soil groupings according to geological formation, 152; soil science as related to, 115
Gibbsite, 126
Glinka, K., 163
Gnaphalium, 61
Gneiss, 168, 193, 208
Goats, 16, 20, 30
Gosline, M., viii
Grains, 58
Grapes, 47; vineyard of Kampoot grapes (ill.), opp. 46
Grass, high and tall, terms, 10
Grass flora, dry forest, 39
Grasslands, Natal, 150; productivity, relative and potential, 228, 229, 230, 233, 237, 240; total area, 18, 19, 21; vegetation types, detailed description, 50
Gray desert soils, 77, 121, 124, 180; productivity, relative and potential, 241
Gray forest soils, 121, 122
Gray sandy soils, 44, 65, 81, 84; productivity, relative and potential, 238, 239

Grazing lands, 17, 18, 20, 69, 77; area, 22
Great Plains country of the United States, 151, 154; mortar beds, 158
Groups of vegetation types. *See* Vegetation groups
Guasa Nyiro, opp. 44
Guillemain, C., 204
Guinea, soils, 181
Gums, 45, 65
Gutierrezia, 63
Gyrophora umbilicarioides, 71

Haematostaphis barteri, 26
Hagenia abyssinica J. F. Gmel., 32, 33
Hahn, Friedrich, 9, 96
Halfa, 11, 67
Hann, Julius, 246
Harmattan, 52
Harrison, J. B., 185
Hatch, F. H., 158, 165, 201
Hébert, Alex., 206
Helichrysum lentii, 72
Herbertson, A. J., 246
Herbivora, 14, 66, 78
Heteropogon hirtus Pers., 56, 61
High forest, 32
High grass, term, 10
High grass-low tree savana, 10; agriculture, 53; area, 19; botanical description, 51; characteristic view (ill.), opp. 50; climatic conditions, 52; coffee plantation (ill.), opp. 52; crop potentialities, 54; detailed description, 50; distribution, 51; manioc plantation (ill.), opp. 53; native agriculture (ill.), opp. 51; natural production, 52; productivity, relative and potential, 230, 231, 233, 236, 237; red brown soil sections (ills.), opp. 194, opp. 195; soil conditions, 52
High Veld, 60; term, 149
Hogs, 16, 30
Holland, T. H., 185
Holmes, R. S., x, 162, 194, 219, 220, 221
Hoodia gordoni Sweet, 79
Horses, 16
Hottentots, 17
Hough, G. J., x, 194, 218, 221
Humus, 158, 171, 179, 197, 218
Humuskalkböden, 157
Hydrargillite, 184
Hydrochloric acid, 133
Hydrous silicate of alumina, 188
Hyparrhenia filipendula (Hochst.) Stapf, 67
Hyparrhenia hirta (L.) Stapf, 56, 61
Hyparrhenia rufa (Nees) Stapf, 39, 51, 68
Hyparrhenia ruprechtii Fourn., 56
Hyphaene, 51
Hyphaene thebaica (Del.) Mart., 48
Hypoxis costata Baker, 61

Igneous rocks, 170; dark-colored, 161, 162
Ilex aquifolium L., 46
Illuvial accumulation, 179
Immature red loams, 190, 205; areas, 207
Imperata cylindrica (L.) Beauv., 51
Imperata cylindrica var. Thunbergii Dur. & Schintz, 51
India, red soil, 117, 181, 185
Indigofera hedyantha Eckl. & Zeyh., 61
Inquiry, vii, x
Inselberge, 170
Investigation, point of view, 115
Ipomoea aquatica Forsk., 74
Ipomoea palmata Forsk., 74
Iron oxide, 182, 202, 203; in laterite, 184; as soil constituent, 125, 127
Iron oxide crust, 200, 202, 205
Irrigation, 49
Ivory, 29, 35
Ivory Coast, 26

Jardinia congoensis Franch., 51
Johnston, Sir H. H., 16, 98, 99
Juniperus procera Hochst., 32
Juritz, C. F., 134, 152, 157; on dark-colored soils, 143, 145, 149

Kaffirs, 17, 72
Kafue, 196
Kalahari, 159, 163; chestnut-brown soils, 173
Kalule Sud, opp. 194
Kaolinite, 208
Karroid plateau, 79
Karroo, 78, 79, 144
Karroo bush, opp. 64 (ill.), 79, opp. 80 (ill.)
Kasai region, 201, 203, 236
Kassala, 164
Keane, A. H., 18
Kearney, T. H., vii
Kenkelbosch, 144
Kenya, Mount, 35, 71, 176
Kenya Colony, chernozems, 157, 161, 175

Khaya spp., 26
Kigelia, 51
Kilimanjaro, Mount, 71, 216; temperate rain forest, 33
Kimberley, opp. 64, 65
Kincer, J. B., vii; note on the rainfall map of Africa, 245
Kindu, opp. 25, opp. 28, opp. 29, 30
Kisumu, opp. 57
Klainedoxa sp., 26
Knox, Alexander, 246
Koedoespoort red loams, 153
Koeleria cristata, 71
Koert, W., 210, 215, 221
Kola nuts, 28, 29
Kombo, 29
Kongolo, opp. 50, opp. 51, opp. 53

Lacroix, Alfred, 186, 189, 194, 200, 202, 206, 208, 209, 211, 216
Ladysmith, 148
Laguncularia racemosa Gaertn., 24
Lamb, P. H., 204
Land, type symbols on land classification map, 226–227
Land classification of Africa, 225; map described, 225
Landolphia, 28
Landolphia owariensis Beauv., 29
Lang, A., viii
Langhans, Paul, 20; vegetation types and areas, 20
Laterite, 117, 121, 125, 126, 190; areas in Africa, 215; Bauer's studies, 183; chemical analysis, results, 184; chemical study of, 118; definition in terms of chemical composition, 186, 189; definition of term as used in this work, 189; detrital and residual, 182; distribution in Africa, 214; high grass-low tree savana, 52; history of ideas regarding, 181; Lake Albert region, 155; loose definition, 132; mountain grassland, 69; processes of development, 187; productivity of lands, relative and potential, 236; red soils distinguished from lateritic, 176; residual and detrital, 182; study of, 117; Transvaal soils, 152
Lateritic clay, 211
Lateritic lithomarge, 186
Lateritic red loams, 28, 52, 190, 208; areas, 209; definition of term as used in this work, 189; productivity, relative and potential, 232
Lateritic soil, term, 186; tropical rain forest, 28
Lecanora esculenta Eversm., 83
Lemoine, Paul, 206, 209, 216, 217
Leucadendron argenteum (L.) R. Br., 46
Leucadendron plumosum R. Br., 46
Leucospermum conocarpum R. Br., 46
Lichens, 71
Light-colored soils of the chernozem group, 166
Lime in chernozem soils, 165
Lime carbonate, 141, 143, 145; chernozem, 157–158; prairie soils, 153; rainfall and, in Natal, 148; Russian soils, 123, 124
Limoniastrum feei Batt., 83
Limpopo River, 167
Lindi, 160
Literature of vegetation, 85
Literature of soils, 131, 137, 140, 141
Lithomargic laterites, 186
Little Karroo, 143, 146
Lobelia, 33, 72
Lommel, V., 207
Lophira alata Banks, 51
Lophira procera, 26
Lophira procera Cheval., 29
Low Veld, 55, 62, 153; soil sample from locality northwest of Pretoria, 156, 157, 218; soils, 158; term, 149
Lualaba River, opp. 73, opp. 74; soil sample, 192, 220
Luffa aegyptiaca Mill., 74
Lumnitzera racemosa Willd., 24
Luxor, opp. 48
Lycium, 79
Lycium arenicolum Miers, 80
Lygeum spartum, Loefl., 80

Macaranga kilimandscharica Pax, 32
Maclaren, Malcolm, 185
Maclear, 149
Macrolobium dewevrei Wildem., 26
Madagascar, 20, 194
Madeira, vegetation, 47
Mahenge, 207
Makindu, 169, 178; soil sample, analysis, 219
Malele, opp. 194
Mangrove forest, 13; agriculture, 25; area, 19; botanical description, 23; climatic conditions, 24; detailed description, 23; distribution, 24; foliage and prop roots at low tide (ill.), opp. 24; natural production, 24;

Mangrove forest (*continued*)
productivity of land, relative and potential, 241; soil conditions, 24
Manihot esculenta, opp. 53
Manioc, 31, 53; plantation (ill.), opp. 53
Manisuris exaltata (L.) Kuntze, 51
Maps, sources, x
Maqui, 13, 45
Marantaceae (ill.), opp. 25
Marbut, C. F., vii, 163
Marchand, B. de C., 152, 153
Marsh grass, 13; agriculture, 75; area, 19; botanical description, 73; climatic conditions, 74; detailed description, 73; distribution, 74; general view (ill.), opp. 73; natural production, 74; oil palms (ill.), opp. 74; productivity of land, relative and potential, 228, 240
Masai, 17
Masai cattle (ill.), opp. 66
Maufe, H. B., 134, 157, 158, 161, 162, 166, 168, 169, 176, 177, 178; Makindu soil sample, analysis, 219
Mediterranean region, 36, 37; red soils, 127; vegetation, 13, 36, 45, 72
Méné de forêt, 29
Mennel, F. P., 201
Merili, opp. 65
Meru, opp. 57, opp. 66
Mesembryanthemum, 79, 80
Mesembryanthemum fimbriatum Sond., 79
Mesembryanthemum moniliforme Thunb., 79
Mesembryanthemum opticum Marloth, 79
Mesembryanthemum rhopalophyllum Schlechter & Diels, 79
Metalasia (ill.), opp. 45
Metalasia muricata R. Br., 46
Meyer, Hans, 102, 207
Microchloa indica (L.) Kuntze, 68
Mimetes lyrigera Knight, 46
Mineral resources, 225
Miombo forest, 37
Misindi, opp. 52
Mitragyna macrophylla, 26
Mlanji, Mount, 213
Monocymbium ceresiaeforme (Nees) Stapf, 61
Mortar beds, 158
Moshi, opp. 35, 221, opp. 194
Mountain grassland, 13; agriculture, 69; area, 19; botanical description, 67; climatic conditions, 69; crop potentialities, 70; detailed description, 67; distribution, 68; even grass cover (ill.), opp. 67; general view (ill.), opp. 68; native field of eleusine (ill.), opp. 69; natural production, 69; productivity, relative and potential, 229; soil conditions, 69
Muff, H. B. *See* Maufe, H. B.
Musanga smithii B. Br., 27
Myrica kilimandscharica Engl., 33
Myrsine africana L., 46
Myrtus communis L., 46

Nairobi, 149; soil sample, 157, 159, 175, 218
Namib, 12, 83, 84
Natal loams, 147, 158
National Research Council, x
Native races, literature, 18; vegetation and, 17
Natural production of the vegetation types, acacia-desert grass savana, 65; acacia-tall grass savana, 57; desert, 84; desert shrub, 81; desert shrub-desert grass, 77; dry forest, 40; dwarf palm-temperate grass, 73; high grass-low tree savana, 52; mangrove forest, 24; marsh grass, 74; mountain grassland, 69; oak-conifer forest, 37; oases, 49; tall grass, 62; temperate brush, 47; temperate rain forest, 34; thorn forest, 45; tropical rain forest, 28
Natural regions, 4
Ndele, 204
N'gano N'gano, opp. 67, opp. 68
Niger River, 163, 212, 213, 238
Nigeria, 163, 212
Niklas, Hans, 198
Nimule, opp. 56, opp. 58
Nitrogen, in chernozem soils, 165; in light-colored chernozems, 170
Njoro, soil section (ill.), opp. 158
Norite black turf, 153
North Africa, soils, 47, 142, 146; vegetation, 13, 36, 45, 72
Nyasa, Lake, region, 207, 213

Oak-conifer forest, 13; area, 19; detailed description, 36; general view of cedar forest (ill.), opp. 36; productivity of land, relative and potential, 232

Oases, 12; agriculture, 49; area, 19; botanical description, 48; climatic conditions, 49; date palms and irrigated land (ill.), opp. 48; detailed description, 48; distribution, 49; natural production, 49; soil conditions, 49
Oberly, E. R., viii
Oil, trees producing, 29
Oil palm, 28, 29, 52, opp. 74 (ill.), 75
Oklahoma, 198
Olea chrysophylla Lam., 32
Olea europea L., 46
Olea hochstetteri Baker, 32
Olea laurifolia Lam., 32
Olea verrucosa Link, 46
Olifants River, 150
Oran, opp. 72
Orange orchard (ill.), opp. 59
Orchard steppe, 8, 55, 63
Origin of soils, term, 140
Ostrich, 17, 47
Othonna cacalioides L., 79

Palms, date, 48; doum, 48; dwarf, 72, opp. 72; oil, 28, 29, 52, opp. 74 (ill.), 75
Panicum madagascariense Spreng., 39
Panicum maximum Jacq., 74
Panicum nigropedatum Munro, 64
Panicum pyramidale Lam., 73
Panicum turgidum Hochst., 76
Papyrus, opp. 73 (ill.), 74, 75
Parinarium tenuifolium, 26
Park land, 8, 55
Parkia africana R. Br., 51
Parmelia adpressa, 71
Parmelia latissima, 71
Passarge, Siegfried, 103, 157, 201, 202
Pastoral tribes, 16
Pechuel-Loesche, Eduard, 96, 104, 146, 220; soil sample from Malanye, 196
Pelargonium, 79
Pelargonium cortusaefolium L'Hérit., 79
Pelargonium crassicaule L'Hérit., 79
Peltophorus sulcatus Stapf, 39
Pennisetum, 51; floating (ill.), opp. 73
Pennisetum benthami, 52
Pennisetum benthami Steud., 51
Pennisetum purpureum Schum., 51
Pennisetum setosum Rich., 51
Pentadesma butyracea Sabine, 29
Pentadesma leucantha Cheval., 29
Pentzia (ill.), opp. 80
Pentzia globosa Less., 79
Pentzia virgata Less., 79
Phoenix dactylifera L., 48
Phosphorus in chernozem soils, 165
Photographs, sources, x
Phragmites communis Trin., 73
Pinus halepensis Miller, 37
Piptadenia africana, 26
Piptadenia spp., 26
Pituranthos aphyllus (DC.) Kuntze, 79
Plant associations, 4, 5
Plant food, 136, 166, 214
Plant formations. *See* Formations
Plant Industry, Bureau of, vii
Playa soils, 145
Podocarpus elongata L'Hér., 32
Podocarpus falcata R. Br., 32
Podocarpus milanjiana Rendle, 32–33
Podocarpus thunbergii Hook., 32
Podocarpus usambarensis Pilg., 32
Podsols, 121
Polygola (ill.), opp. 45
Polygola, opp. 45 (ill.)
Polygonum senegalense Meissn., 74
Port Bell, opp. 195
Port Elizabeth, 144, 157
Portulacaria afra Jacq., 43
Prairie soils, 121, 125; of the Transvaal, 62, 151, 164; tropical, 155, 212; of the United States, 155, 172
Pretoria, opp. 60, 149, 156, 157
Pretoria quartzite sandy soils, 153
Production. *See* Natural production
Productivity, land classification according to, 225; method of indicating grades on land classification map, 226
Productivity, relative and potential, of land according to soil type, 227; alluvium, light-colored, 227; brackish swamp soil, 241; brown soils with reddish subsoils, 232; brown sandy loams, or heavier, unleached, high in soluble contents, 240; brown to dark-brown soils with calcareous subsoils, 237; dark brown to red-brown, sandy loams to loams, 230; dark-colored humid soils, 231; dark-colored soils, often calcareous subsoils, 233; dark reddish loams, free from hardpan, moderately leached and moderately complex, 229; gray sandy desert, 241; gray to red sands not extensively leached, 239; gray to red soils, often heavy subsoils, 235; gray, wet, sandy alluvium, often charged with salts, 240; grayish sands with considerable

Productivity, relative and potential, of land according to soil type (*continued*)
organic matter, moderately leached, 238; heavy black soil, 231; laterites, 236; red loams, moderately deep, no hardpan, moderate leaching, 228; red loams moderately leached, 229; red loams occasionally dark in color, 234; red loams probably lateritic, 232; red loams, with iron oxide accumulation in the subsoils, Kasai basin, 236; red loams and sandy loams, 234; sands and dark-colored sandy alluvial soils of the Lake Chad basin and bend of the Niger, free from hardpan, 238
Productivity, relative and potential, of land according to vegetation type, 227; acacia-desert grass savana, 239; acacia-tall grass savana, 231, 233, 235, 237, 238, 239; alpine meadow, 241; desert, 242; desert grass-desert shrub, 237, 241; desert shrub, 241, 242; dry forest, 234, 235, 240; dwarf palm-temperate grass, 237; high grass-low tree savana, 230, 231, 233, 236, 237; mangrove forest, 241; marsh grass, 228, 240; mountain grassland, 229; oak-conifer forest, 232; tall grass, 230; temperate brush, 232; temperate rain forest, 228; tropical rain forest, 228, 233, 236
Protea grandiflora Thunb., 46
Protea kilimandscharica, 72
Protea lepidocarpodendron L., 46
Protea mellifera Thunb., 46
Protea neriifolia R. Br., 46
Prunus spinosa L., 46
Pseudolachnostylis maprouneaefolia Pax, 38
Pteridium aquilinum (L.) Kuhn., 33
Pterocarpus angolensis DC., 38
Pterocarpus erinaceus Lam., 38
Pteronia succulenta Thunb., 79
Pycnanthus sp., 29

Quartz, 126, 127, 184, 187, 208
Quercus ilex L., 37, 46
Quercus lusitanica Lam., 37

Races. *See* Native races
Raffia, 28, 29
Rainfall, in chernozem belt and chestnut-brown soil belt, 171; chernozems and, 160; importance in soil development, 129, 148
Rainfall map of Africa, note, 245
Raphia, 27
Ratzel, Friedrich, 18, 105
Rauwolfia macrophylla Stapf, 27
Raven, H. C., viii
Red loams, 34, 40, 44, 52, 65, 69, 73, 121, 125, 127, 190, 192; analysis and composition, 194, 196, 219, 220; areas, 193, 196, 199; building blocks, Uganda, probably lateritic (ill.), opp. 195; definition of term as used in this work, 189; deserts, 77; dry forest, 40; high grass-low tree savana, 52; lateritic, 208 (*see also* Lateritic red loams); mountain grassland, 69; Natal loams and, 147, 151; position in relation to chernozems and laterites, 197; section south of Malele on the Lualaba (ill.), opp. 194; productivity, 199; productivity, relative and potential, 228, 229, 234, 236; section at Embu (ill.), opp. 194; section at Kalule Sud (ills.), opp. 194, opp. 195; section at Moshi (ill.), opp. 194; section at Port Bell (ill.), opp. 195; temperate rain forest, 34
Red River valley, 159
Red sandy soils, 40, 44, 65, 77, 81, 168; chernozems and, 170; productivity, relative and potential, 239
Red soils, distinguished from laterite, 176
Redness of soil, 131, 132, 181
References, 23; list of, 85
Rejaf, opp. 56, opp. 58
Rendzinas, 157, 158
Rhigozum (Rhizogum), 63
Rhigozum trichotomum Burch., 80
Rhizophora mangle L., 24
Rhizophora mucronata Lam., 24, opp 24 (ill.)
Rhodesia, soils, 134, 154
Rhus tomentosa L., 46
Rikli, M., opp. 36, 105
Robinson, W. O., x, 162, 194, 195, 218 219, 220
Rock decomposition in the tropics, 187 208
Rocks in tropical Africa, 198
Rooi grass, 60
Root crops, 42
Roterde, 189
Rubber, 28, 29, 31, 35
Rudolph, Lake, 176
Rupprecht, ———, 119

Russia, chernozem, 118; chestnut-colored soils, 173
Russians, soil groups established by, 121
Rustenberg, opp. 59
Ruwenzori, Mount, 34, 71

Sage brush, 78
Sahara, 12, 83, 84; chestnut-brown soils along southern border, 174; desert soils, 179, 180; oases, 49
Sakania, 39
Salicornia fruticosa L., 82
Salix safsaf Forsk., 48
Salsola aphylla L., 82
Salsola zeyheri H. & B., 83
Salt accumulations, 179
Salt desert shrub, 12, opp. 81 (ill.); agriculture, 82; area, 19; botanical description, 82; detailed description, 81; distribution, 82
Salvadora persica L., 80
Sands, productivity, relative and potential, 238
Sandstone, 168, 170, 198
Sandy loams, dry forest, 40; productivity, relative and potential, 230, 234, 240
Sandy soils, Natal, 147; productivity, relative and potential, 238; red, 40, 65, 77, 168
Sansevieria longiflora Sims, 43
Sansevieria thrysiflora Thunb., 44
Sarcocaulon burmanni DC., 79, 83
Sarcocephalus spp., 26
Sarcoglottis gabonensis, 26
Savana, term, 7
Sawyer, A. R., 147
Saxenwald, 44
Schaffer, T., viii
Schmidtia bulbosa Stapf, 64
Schnee, Heinrich, 209
Schotia speciosa Jacq., 43
Schröter, Carl, 5, opp. 36, 93, 105
Schwager, A., 196, 220
Scirpus corymbosus Heyne, 74
Sclerocarya caffra Sond., 56
Scrivenor, J. B., 185
See, K. von, 158
Senecio, 33, 72
Senegal, 211, 213
Setaria aurea, 71
Setaria aurea Hochst., 39, 74
Setaria sp., 39
Seychelle Islands, 183
Shaler, M. K., 182, 200, 201, 203
Shantz, H. L., vii–x, 107, 137, 144, 152, 154, 174, 196; Bulawayo soil sample, 157, 218; Low Veld, northwest of Pretoria, soil sample, 156, 157, 218; Lualaba River soil sample, 192, 220; Nairobi soil sample, 157, 159, 175, 218; route (map), viii–ix; Shikaba soil sample, 157, 159, 163, 218; Urundi soil sample, 191–192, 209, 220; Vereeniging soil sample, 202
Shari-Chad region, 163
Shea tree, 52
Sheep, 16, 20
Shikaba, soil sample, 157, 159, 163, 218
Shrubby plants, 78
Silica, 126, 127, 187
Silicate of alumina, 188
Siliceous laterites, 186, 211
Skeels, H. C., x
Smit, B. J., 137, 152, 153, 166
Soil analysis, 133, 135. *See also* Analysis of soils
Soil conditions of the vegetation types, acacia-desert grass savana, 65; desert, 84; desert shrub, 81; desert shrub-desert grass, 77; dry forest, 40; dwarf palm-temperate grass, 73; high grass-low tree savana, 52; mangrove forest, 24; mountain grassland, 69; oak-conifer forest, 37; oases, 49; tall grass, 62; temperate brush, 47; temperate rain forest, 34; thorn forest, 44; tropical rain forest, 28
Soil family, 129
Soil map of Africa, principles of construction, 137
Soil material, 116, 120, 128, 139
Soil samples, 138; analyses, 137, 218–221; collection for present work, ix, 137
Soil science, modern development, 117; principles, 115; results of geographic significance, 120
Soil scientists, 131
Soil texture, 139, 199
Soils, African, literature, 137; African, past and present study, 131; African, principles followed in classifying, 137; arid regions of Africa, 179; belts coincident with climatic belts, 120; classification, 121; classification according to geological formation, 152; climatic forces as dominant influence on, 138; criteria for classi-

Soils (*continued*)
fication, 139; development, 128; development, influences, 139; distribution in belts different from geological formations, 120; features of importance, 130–141; groups established outside of Russia, 124; as instrument for crop production, 116; parent materials of, 116, 120, 128; as product of climatic forces, 119; redness, 131, 132, 181; Russian investigators' groups, 121; study by geologists and by agronomists, 115; subtropical Africa, 142 (*see also* Temperate soils); temperate Africa, 142 (*see also* Temperate soils); topography as related to, 128; tropical Africa, 181 (*see also* Tropical soils)
Soils, Bureau of, vii, 137, 162, 194
Somaliland, brown desert soils, 180; chestnut-brown soils, 175, 176; plateau, 165
Sonneratia caseolaris (L.) Engl., 24
Sorghum, 41, 58, 66; native field (ill.), opp. 57
Sorghum arundinaceum (Willd.) Stapf, 74
Sour veld, 57
South Africa, soil students and their groupings of soils, 152; soil studies, history, 134; soils, 142; Texas compared with, 156
Spathodea campanulata Beauv., 27
Sporobolus pyramidalis Beauv., 68
Statice scabra Thunb., 83
Staudtia gabonensis, 26
Steppe, term, 7
Steppenkalk, 168, 170
Stipa tenacissima L., 76
Strychnos, 51
Strychnos pungens Solored., 38
Strychnos schumanniana Gilg, 38
Suaeda (ill.), opp. 81
Suaeda baccata Forsk., 82
Suaeda maritima Dum., 82
Suaeda monoica Forsk., 82
Suaeda vermiculata Forsk., 82
Subtropical soils. *See* Temperate soils
Succulents, 78, opp. 81 (ill.), 83
Sudan, soils, 142
Sultan Hamud, 169
Supan, Alexander, 246
Süssenguth, H., 221
Swamp soils, 144; productivity, relative and potential, 241
Swamps, 169, 201; 205
Sweet potatoes, native planting (ill.), opp. 58
Sweet veld, 57

Table Mountain, temperate brush (ill.), opp. 45
Tagetes minuta L., 61
Tall grass, 10; agriculture, 62; area, 19; botanical description, 60; climatic conditions, 62; detailed description, 60; distribution, 62; natural production, 62; productivity of land, relative and potential, 230; soil conditions, 62; soil section at Njoro (ill.), opp. 158; typical high veld (ill.), opp. 60; typical view (ill.), opp. 61
Tama de forêt, 29
Tamarix, 48, 82
Tamarix articulata Vahl, 48
Tamarix gallica L., 48
Tanbark, 37
Tanganyika, Lake, region, 155
Tanganyika Territory, 166, 168, 207, 210; laterites, 215
Tansley, A. G., opp. 36, 105
Tarchonanthus camphoratus L., 43, 64
Taungs, section of chestnut-brown soil (ill.), opp. 158
Temperate brush, 13; agriculture, 47; area, 19; botanical description, 45; climatic conditions, 47; crop potentialities, 48; detailed description, 45; distribution, 46; general view (ill.), opp. 45; natural production, 47; productivity of land, relative and potential, 232; soil conditions, 47, 142; vineyard (ill.), opp. 46
Temperate forest of Cape, productivity of land, relative and potential, 232
Temperate rain forest, 12; agriculture, 35; area, 19; botanical description, 32; climatic conditions, 34; crop potentialities, 35; detailed description, 32; distribution, 33; general view (ill.), opp. 32; interior detail (ill.), opp. 33; mixed culture (ill.), opp. 35; native fields (ill.), opp. 34; natural production, 34; productivity of land, relative and potential, 228; red loam soil sections (ill.), opp. 194; soil conditions, 34
Temperate soils, 142; brown soils of the Cape Province and Atlas region, 142; chernozems, 156; chestnut-

Temperate soils (*continued*)
brown soils, 170; light-colored soils of the chernozem group, 166; Natal loams, 147; prairie soils of the Transvaal, 151
Terminalia sericea Burch., 39, 56, 64
Terminology, 7
Termite hills, 38, 60
Termites, 17, 41
Terra rossa, 127, 189
Texas, chernozem and chestnut-brown soils, 176; chernozems in, 160; chernozems, red and black, 177; mesquite-covered plains, 198; prairie soils, 154; South Africa compared with, 156
Texture of soil, 139, 195
Themeda, 57; almost pure stand (ill.), opp. 60
Themeda triandra Forsk., 56, opp. 57, 60, 61, 68
Thorn bush steppe, 63
Thorn forest, 11; acacia thicket (ill.), opp. 44; area, 19; botanical description, 42; climatic conditions, 44; detailed description, 42; distribution, 44; natural production, 45; soil conditions, 44
Thorns, 42
Thurlemann, L., viii
Thyrsia sp., 39
Timber, 34; on Natal loams, 150; tropical rain forest, percentage available in three regions, 26
Timberland, 17; area, 18, 21
Topography, importance in soil development, 128; relation of soil to, 138
Transvaal, chernozem areas, 165; dark-colored soils, 145; light-colored soils, 166; soils, 151
Tree steppe, 37, 55
Tribes, native, as related to vegetation, 17; pastoral, 16, 66
Trichocaulon cactiformis N. E. Br., 79
Tricholaena rosea Nees, 39, 68
Trichopteryx gigantea Stapf, 39
Trichopteryx gigantea gracilis Rendle?, 39
Trichopteryx sp., 67
Trisetaria quinqueseta, 71
Tristachya rehmanni Hack., 61
Tropical prairie soils, 155, 212
Tropical rain forest, 9; agriculture, 30; area, 19; botanical description, 26; climatic conditions, 27; coffee plantation (ill.), opp. 29; crop potentialities, 31; detailed description, 25; distribution, 27; foliage (ill.), opp. 25; native plantation (ill.), opp. 28; natural production, 28; productivity of land, relative and potential, 228, 233, 236; soil conditions, 28; term, 4; timber available in three regions, 26
Tropical rain forest (*continued*)
Tropical soils, 181; ferruginous red loams, 190, 199; general characteristics, 190; immature red loams, 190, 205; lateritic red loams, 190, 208; laterites, 190, 214 (*see also* Laterite); red loams, 190, 192
Tsavo, 176
Tucker, M. P., vii
Tuff, 158, 165
Tundra soils, 121
Types of vegetation. *See* Vegetation types
Typha angustifolia L., 73

Uapaca spp., 26
Ubangi-Shari region, 205
Uganda, building blocks, probably lateritic (ill.), opp. 195
Uganda Railway, 166, 168, 169, 176, 178
Umbilicaria pustulata, 71
Urundi, soil sample, 191–192, 209, 220; upland, 154
Usambara highlands, 207, 210, 215

Vallisneria sp., 74
Van Eseltine, G. P., x
Vegetation, as a criterion, 7; broad belts as basis of classification, 8; correlation with other distributions, 13
Vegetation groups, 18; areas of major subdivisions, 21
Vegetation map of Africa, basis, 8
Vegetation types, 3; areas occupied by each, 18, 19; classification, principles, 3; Langhans' classification, 20; list, general description, 9; measurement of areas, 18
Veld, Eastern Grass, 150; High, 60, 149; Low, 50, 62, 149, 153, 156, 157, 158, 218; sour and sweet, 57; term, 7
Vereeniging, opp. 61, 152, 154; soil sample, 202
Vineyard, temperate brush (ill.), opp. 46

Vitex pachyphylla, 26
Vlei soils, 147, 148, 158
Vossia procera Wall. & Griff., 74

Wadi Halfa, opp. 82
Wagner, Hermann, 20
Warner, M. F., viii
Warth, H. and F. J., 183
Wattle, 36, 60, 232
Watusi, 17, 69, opp. 69
Wead, K., viii
Weather Bureau, vii
Weathering in the tropics, 185, 187, 188
Weenen, 148
Welwitschia mirabilis Hook., 83
White alkali, 81
Williams, C. O., 147, 148
Wine, 47
Wohltmann, Ferdinand, 112, 136, 146, 182, 207, 216; agrogeological institute, 210
Woodland, area, 18, 21
Worcester, 143
Wynberg, opp. 46

Xylocarpus obovatus A. Juss., 24

Yams, 35
Yellow soils, 121, 124

Zambezi River, hill region, 167
Zizyphus, 48
Zizyphus lotus Lam., 80
Zizyphus mucronata Willd., 38, 43, 57, 64
Zizyphus spina-Christi Willd., 48, 56, opp. 56 (ill.)

ERRATA

p. 48, last line, for Forks. read Forsk.
p. 79, line 10 of list, for Schlecter read Schlechter
p. 80, line 2 of list of botanical names, for *aretoides* read *aretioides*

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